RELEVANCE AND APPLICABILITY OF FORENSIC SCIENCE IN THE ADMINISTRATION OF CRIMINAL JUSTICE SYSTEM IN INDIA: PROSPECTS AND CHALLENGES

A thesis submitted to the
UPES

For the award of
Doctor of Philosophy
in
Law

BY
Bharti Nair Khan

May 2025

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UPES
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DECLARATION

I declare that the thesis entitled **Relevance and Applicability of Forensic Science in the Administration of Criminal Justice System in India: Prospects and Challenges** has been prepared by me under the guidance of Dr. Sujata Bali, Associate Professor of School of Law, UPES. No part of this thesis has formed the basis for the award of any degree or fellowship previously.

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CERTIFICATE

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ABSTRACT

Forensic science is considered to be a science used along with the law in a fair and just settlement of disputes. It is an important handmaiden of law expected to assist with the resolution of conflicts.

Forensic Science is generally the application of scientific processes, information, knowledge, rules and principles to reach out to the solution for legal questions.

Three decades ago, forensic investigation was considered to be religiously a multi branched study that could with the help of rigorous practice, patience, easily trace and determine the accused beyond reasonable doubts. The capabilities of forensic criminalists to resolve a case were undoubtedly believed and subsequently forensic science began to be frequently used in criminal investigations.

The *Oxford English Dictionary* describes "*forensic science*" as a "*mixed science*". The early use of forensic science was somewhat in a mixed manner when science was applied to the ambiguous questions for catering justice in the court. Forensic science has witnessed tremendous growth and is in a transitional phase. Considering the use of forensic science in cracking down criminal cases for the interest of the public, it is believed to have a hectic and active future.

The word Forensic can be interpreted to mean a term related to the public or a matter of legal concern.

Together the words *Forensic Science* can be used to refer to a discipline or a branch of science dealing with collection, investigation, interpretation, and analysis of data used by the criminalists to answer the doubts and questions generally faced by the courts. For the public forensic science is no less than a miracle used by police to decipher cold cases that had earlier hindered criminal investigation. It can easily destruct the accused alibi and establish the guilt by simply inspecting a small piece of evidence generally not seen by the naked eyes.

To tackle the growing and variant nature of crimes it is pertinent that the rules and laws are simultaneously amended and modified. The investigative and law enforcement agencies are highly dependent on forensic criminalists for scientific advice and support. Forensic science plays a very important role in the administration of the criminal justice system in India. The role and ability of criminalists in furnishing authentic and pertinent details relating to the evidence collected at the scene of the crime is extremely important in resolving the case. Forensic science entails different scientific specialties and branches with the assistance of which pieces of evidence are examined to determine and divulge facts concerning the prosecution or defense in legal proceedings.

Great efforts and errorless use of scientific procedures are necessary to avoid bias and discrepancies. The use of Forensic science in the examination and analysis of physical evidence found at the scene of a crime is well accepted as an important part of the criminal investigation. The materials and the traces obtained from the crime scene are inspected and analyzed throughout the investigation and at the later stage during courtroom sessions to ascertain the truth. The criminalists and the interpretive experts help the court to understand how the evidence is related to the case at hand. Forensic science has its own limitations, which are almost known to all the forensic criminalists and experts. To prove its efficacy the methodologies and analysis done by forensic science have to stand up to the test and challenges of the legal system. Forensic methods and techniques should be applied in an impartial and rational manner to maintain the sanctity and purity of the data and information derived from the crime scene.

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ABBREVIATIONS

1.	**AAFS**	American Academy of Forensic Sciences
2.	**AFIS**	Automated Fingerprint Identification System
3.	**BPR&D**	Bureau of Police Research and Development
4.	**BNS**	Bharatiya Nyaya Sanhita
5.	**BNSS**	Bharatiya Nagarik Suraksha Sanhita
6.	**BSA**	Bharatiya Sakshaya Adhiniyam
7.	**CCI**	Central Criminal Intelligence
8.	**CMLAC**	Central Medico-Legal Advisory Committee
9.	**CFI**	Central Forensic Institute
10.	**CFSL**	Central Forensic Science Laboratory
11.	**CID**	Criminal Investigation Department
12.	**CIO**	Central Intelligence Officers
13.	**CJS**	Criminal Justice System
14.	**CrPC**	Criminal Procedure Code
15.	**CSI**	Crime Scene Investigation
16.	**CTDS**	Central Detective Training School
17.	**DNA**	Deoxyribonucleic Acid
18.	**FBI**	Federal Bureau of Investigation
19.	**FI**	Forensic Institutions
20.	**FRS**	Fellow of the Royal Society

21. **GEQD**	Government Examiner of Questioned Documents
22. **IAFS**	Indian Academy of Forensic Sciences
23. **IB**	Intelligence Bureau
24. **IDB**	Inter-American Development Bank
25. **IG**	Inspector General
26. **INTERPOL**	International Criminal Police Organization
27. **IP**	Indian police
28. **IPC**	Indian Penal Code
29. **ITA**	Immoral Traffic Act
30. **JSTOR**	Journal Storage
31. **NCRB**	National Crime Records Bureau
32. **NIJ**	National Institute of Justice
33. **SACC**	Scientific Advisory Committee to the Cabinet
34. **SCFS**	Standing Committee on Forensic Science
35. **SFPBs**	State Fingerprint Bureaus

CHAPTER I

INTRODUCTION

1.1.Introduction

Forensic science is considered to be a science used along with the law in a fair and just settlement of disputes. It is an important handmaiden of law expected to assist with the resolution of conflicts.

Forensic Science is generally the application of scientific processes, information, knowledge, rules and principles to reach out to the solution for legal questions.

Three decades ago, forensic investigation was considered to be religiously a multi branched study that could with the help of rigorous practice, patience, easily trace and determine the accused beyond reasonable doubts. The capabilities of forensic criminalists to resolve a case were undoubtedly believed and subsequently forensic science began to be frequently used in criminal investigations.

The *Oxford English Dictionary* describes "*forensic science*" as a "*mixed science*". The early use of forensic science was somewhat in a mixed manner when science was applied to the ambiguous questions for catering justice in the court. Forensic science has witnessed tremendous growth and is in a transitional phase. Considering the use of forensic science in cracking down criminal cases for the interest of the public, it is believed to have a hectic and active future.

The word Forensic can be interpreted to mean a term related to the public or a matter of legal concern. Together the words *Forensic Science* can be used to refer to a discipline or a branch of science dealing with collection, investigation, interpretation, and analysis of data used by the criminalists to answer the doubts and questions generally faced by the courts.

For the public forensic science is no less than a miracle used by police to decipher cold cases that had earlier hindered criminal investigation. It can easily destroy the accused alibi and establish the guilt by simply inspecting a small piece of evidence generally not seen by the naked eyes. To tackle the growing and variant nature of crimes it is pertinent that the rules and laws are simultaneously amended and modified. The investigative and law enforcement agencies are highly dependent on forensic criminalists for scientific advice and support. Forensic science plays a very important role in the administration of the criminal justice system in India. The role and ability of criminalists in furnishing authentic and pertinent details relating to the evidence collected at the scene of the crime is extremely important in resolving the case. Forensic science entails different scientific specialties and branches with the assistance of which pieces of evidence are examined to determine and divulge facts concerning the prosecution or defense in legal proceedings.

Great efforts and errorless use of scientific procedures are necessary to avoid bias and discrepancies. The use of Forensic science in the examination and analysis of physical evidence found at the scene of a crime is well accepted as an important part of the criminal investigation. The materials and the traces obtained from the crime scene are inspected and analyzed throughout the investigation and at the later stage during courtroom sessions to ascertain the truth. The criminalists and the interpretive experts help the court to understand how the evidence is related to the case at hand. Forensic science has its own limitations, which are almost known to all the forensic criminalists and experts. To prove its efficacy the methodologies and analysis done by forensic science have to stand up to the test and challenges of the legal system. Forensic methods and techniques should be applied in an impartial and rational manner to maintain the sanctity and purity of the data and information derived from the crime scene.

1.2.Statement of Problem

Forensic evidence functions within the ambit of a legal framework. Forensic science assists experts entrusted with carrying on criminal investigations and helps in the recognition of authentic information, which can be relied on by the court to adjudicate criminal cases. The application of scientific investigation in the criminal justice system has been initiated for the best of reasons. In the absence of scientific techniques, courts and judicial authorities were dependent on the different mechanisms and sources as statements of witnesses, who were at times biased, threatened, influenced, a confession obtained by torturing the suspect, subjecting a person to different ordeals to establish his guilt or innocence. A criminal justice system that relies on confession shall in long run be less reliable and shall be prone to more abuse and misuse as compared to a system that follows extraneous evidence collected independently through skillful and scientific evidence. The application of science thus makes it possible to resolve the ambiguities surrounding crime investigation and makes it more humane.

In the administration of the criminal justice system, the courts rely heavily on the reports and testimony of the experts while deciding the guilt and innocence of the person. The Indian Evidence Act 1872 (now The Bharatiya Sakshya Adhiniyan, 2023) mandates the Judges before admitting the reports furnished by the forensic experts to verify it with the help of expert evidence. Failure of judges to effectively perform gate-keeping responsibilities of verifying the authenticity of forensic science evidence results in injustice.

The herculean task before the Judiciary is how to make maximum utilization of the work done within the scientific sphere to enhance and make better use of forensic science in court. Ensuring proper use of forensic evidence in criminal proceedings is quite challenging because lawyers, as well as the judges, are mostly ignorant of scientific background and education. The lawyers and the judges in the court generally, due to ignorance of scientific studies, may fail to acknowledge and verify the evidence expertly. There is a need to establish and start forensic education courses and programs in various legal institutions and judicial organizations.

Forensic science has now become extremely pertinent in the criminal adjudication process and initiates with the establishment of crime. It is important that the officials at the crime scene cautiously collect and preserve it so that later it is examined by forensic criminalists.

The correct analysis and interpretation of evidence in the realm of criminal justice holds paramount importance in ensuring the efficient operation and authority of justice systems in democratic nations. Consequently, a perpetual imperative exists to continually enhance the precision and dependability of forensic analytic methodologies, commonly referred to as forensic science. The optimal approach for addressing this requirement entails harnessing the comprehensive potential of scientific inquiry to address inquiries and methodologies within the realm of forensic science.

The presence of dependable and accurate forensic science analytical methodologies holds utmost significance in establishing a reputable, equitable, and empirically grounded criminal justice framework. There exists a consensus among scholars that the scientific underpinnings of certain

forensic science methodologies presently in use necessitate fortification, while the development of supplementary, more efficacious approaches is of utmost importance and immediacy. The fulfilment of these demands can solely be achieved through the implementation of continuous research initiatives that are explicitly formulated to guarantee and enhance the dependability and accuracy of existing methodologies, while simultaneously promoting the advancement and use of novel and superior processes The present undertaking presents a formidable challenge, owing to the expansive scope inherent within the domain under consideration. The realm of forensic science encompasses a broad spectrum of concerns, spanning from the meticulous examination of crime scenes to the comprehensive analysis of diverse forms of evidentiary material Furthermore, the practice of forensic science is enriched by a multitude of diverse fields of study, encompassing but not limited to biology, chemistry, statistics, and various additional areas of study. In light of

the various obstacles encountered by forensic science laboratories, including limited resources, overwhelming caseloads, and discrepancies in operational structures across state and local jurisdictions, it is imperative that national leadership takes immediate action to establish and maintain a comprehensive initiative of exceptional calibre.

1.3.Research Questions

The research questions addressed during the study are:

1. How the discipline of forensic science has evolved in India and which significant legislation and precedents contributed to its development?
2. What is the relevance and role of forensic science in determining the accuracy and authenticity of evidence, reports and documents furnished before the courts?
3. What challenges exist that affect the authenticity and admissibility of forensic science?
4. Whether there is a need for comprehensive legislation to regulate the application of forensic science in the criminal investigation.
5. How can synergy be built between the judiciary, investigative agencies and forensic experts?
6. Whether there exist any shortcomings that need to be addressed for capacity building of forensic studies in India?
7. What suggestions can be put forth to strengthen the discipline of forensic science in India?

1.4.Objectives of the Study

1. To study and understand the historical perspective and significant legal changes in the development of forensic science.
2. To analyze and study the relevance of forensic science in determining the guilt or innocence of a person and assisting in timely and infallible administration of the criminal justice system in India.

3. To ascertain and highlight the use and application of forensic science in the criminal investigation of cases.
4. To study and address the challenges related to the admissibility and authenticity of forensic evidence.
5. To analyze and address the ways of building synergy between the judiciary, investigative agencies and criminalists
6. Based on the study and findings, to address the gaps between theory and practice in the discipline of forensic science.
7. To suggest changes in the existing legal framework of the criminal justice delivery system in line with the research findings.

1.5.Conceptual Framework

Before the application of legal and scientific principles for resolving the cases, evidence was scrutinized and verified in a mysterious, superficial, magical manner that varied from country to country. There has been a long influence of religion and spiritual belief on evidence. A suspect was subjected to the various test like judicial duel and cross ordeal to draw evidence in line with God's judgment. Despite these methods of extracting data believing to have Godly origin still, turned out to be limited and societies looked forward towards other methods like confessions and statements and testimony of witnesses. Simultaneously help from various experts like physicians were taken for the disclosure of facts and their opinion would help the jury to know the cause of the demise of the deceased. At the beginning of the sixteenth century in France assistance of handwriting experts, were taken by the courts to adjudicate forgery cases. Technical and scientific expertise was frequently required during the investigations and trials even when relying on confession and statements of witnesses was the modus operandi in criminal proceedings. Therefore, there was an advancement of scientific and technical progress in the field of law, which was necessary to corroborate the evidence drawn through testimony, admission and confession. In the mid of nineteenth-century because of the growing role of a forensic scientist, altogether new perceptions and ideas concerning science

and law were introduced. Society was not satisfied with the criminal proceeding being completely dependent on confession. Therefore, science had to intrude into criminal proceedings to restore the faith of the public in the criminal justice system. In early 1893, Austria imposed mandatory training in forensic science for judicial officers and lawyers. The training helped the judges to understand the importance of science in legal proceedings. In 1876 there was a new research movement started in Italy. This movement discarded the old and obsolete born criminal theory and held different observations such as a man with a tattoo being a potential criminal or a man with a sharp nose and eyes having a criminal tendency to be absurd and unscientific.

The adversarial Judicial System in the USA led to the rapid acceptance and frequent use of forensic science in criminal proceedings. The First United States Police crime laboratory was established in the year 1920.

Forensic science is evolving and expanding in different new fields by devising new techniques and procedures, therefore, proving to be more significant and relevant. After US Daubert's case, the judges are required to establish that the evidence and testimony furnished by the expert are authenticate and reliable. The courts have to verify that the expert possessed the required scientific knowledge, experience and had diligently made use of the process and methods while applying it to the facts at hand. Not much is known about the background and knowledge of Judges in Forensic Science and the kind of scientific training they underwent in scientific evidence. The Judges are entrusted with the gatekeeping role of evaluating the forensic reports furnished by the experts. The authentication and admissibility of the reports are generally decided by the judges who themselves know nothing about the forensic discipline.

1.6.Literature Review

A. Books

The available literature has been examined to develop a better understanding of some of the specific components of forensic justice. The review has enabled the

determination of the grey areas, which need to be researched to develop a comprehensive understanding of the relationship between the discipline of forensic science and the criminal justice system.

Prof. (Dr.) Nuzhat Parveen Khan, in his book "Forensic Science & Indian Legal System" 2022, has aimed to provide an extensive study of the relationship between forensic science and the Indian criminal justice system. Each chapter of the book has been designed in such a way that it presents an extended sub-discipline of forensic science and its application in the Indian legal system. This book is a must-read for lawyers, judges, academicians, researchers, law students, and any forensic science enthusiast who seeks to grasp the knowledge of the practical applicability of forensic science techniques in the criminal justice system.

B. R. Sharma, in his book "**Forensic Science in Criminal Investigation and Trials 2020"** has intended to assist the criminal justice system to understand the potentialities, the limitations and the process of forensic science. It is an encyclopedic comprehensive guide, a practical multi-professional treatise, written in non-technical language.

Julie Anne Schuck in her book **"Personnel Selection in the Pattern Evidence Domain of Forensic Science: Proceedings of a Workshop" (2017)**
summarizes the presentations and discussions from the workshop convened by the National Academies of Sciences, Engineering, and Medicine with the goal of bringing together industrial and organizational (I-O) psychologists, experts, forensic scientists, and other researchers whose work has a nexus with the workforce.

Hon. Donald, Shelton and Hon Shelton in their book **"Forensic Science in Court: Challenges in the Twenty-First Century" (2016)** have explored the legal implications of forensic science in Court—an increasingly important and complex

part of the justice system. Judge Donald Shelton provides an accessible overview of the legal issues, from the history of evidence in court, to "gatekeeper" judges determining what evidence can be allowed, in the court. The book describes and evaluates various kinds of evidence, including DNA, fingerprints, handwriting, hair, bite marks, tool marks, firearms and bullets, fire and arson investigation, and bloodstain evidence. Assessing the strengths and limitations of each kind of evidence, the author also discusses how they can contribute to identifying the "who," "how," and "whether" questions that arise in criminal prosecutions. Author Donald Shelton draws on the depth of his experiences as a courtroom prosecutor, professor, and judge, to provide a well-rounded look at these increasingly critical issues. Case studies throughout help bring the issues to life and show how forensic science has been used, both successfully and not, in real-world situations.

Donald E. Shelton in his **book "Forensic Science Evidence: Can the Law Keep Up with Science" (2015)** describes the startling questions that have arisen about the reliability of many forms of scientific evidence which were traditionally regarded as reliable and have been routinely admitted to prove guilt. The exonerations resulting from the development of DNA have exposed the lack of trustworthiness of much of the "scientific" evidence that was used to convict people who turned out to be innocent. The author discloses that many courts continue to routinely admit such evidence in criminal cases, despite the obligation of judges to be the "gatekeepers" of the forensic science evidence

Douglas H. Ubelaker in the book **"The Global Practice of Forensic Science Forensic" (2015)** has highlighted the histories, issues, patterns, and diversity in the applications of international forensic science. The book documents the practice of forensic science in 28 countries from Africa, the Americas, Asia, Australia and Europe. The research explores each country's factors of political history, academic linkages, legal issues, future directions and research.

Michael J. Allen in his book **"Foundations of Forensic Document Analysis: Theory and Practice" (2015)** has aimed primarily at students studying forensic

science and document examination in particular, the book introduces all of the essential ideas that are to be found in the work of the forensic document examiner concisely and straightforwardly. Each examination type is described in terms of not only its procedural basis but also the science and reasoning that underpins it.

David Baldwin, John Birkett, Owen Facey, and Gilleon Rabey in their book **"The Forensic Examination and Interpretation of Tool Marks" (2013)** have brought together key techniques and developments in the field of tool marks in forensic science and explains clearly how tool mark analysis can be used within the forensic investigation. The book brings together as much of this information as possible in an accessible manner. The book deals with all aspects of tool mark evidence from a crime scene to the courtroom. The examination of a wide variety of different tool marks are discussed, including those made by specific tools such as saws and in complex materials such as bone. The book brings together key techniques and developments within the field of tool mark investigation. Includes material on examining tool marks at the crime scene and in the laboratory, interpretation and evaluation issues and how tool mark evidence should be presented in court.

Marcel Danesi in the book **"Signs of Crime: Introducing Forensic Semiotics" (2013)** has introduced the field of forensic semiotics as a tool for understanding crime and criminality. It focuses on how symbolism, ritual, and other sign-based activities play a crucial role in the constitution of criminal organizations and often in the enactment of individual crimes. The book presents semiotic notions, methods, and techniques that can be applied to forensic science.

Robert C. Williams in this book "The Forensic Historian: **Using Science to Reexamine the Past" (2013)** Brandonas in detail explained that how forensic science has significantly affected historical debate over some well-known past crimes or mysteries, utilizing modern DNA, nuclear, and chemical analyses to reexamine the past. This book takes an in-depth look at 20 significant cases where

investigators have applied new forensic techniques to confirm, dispute, or revise accepted historical accounts.

This paper discusses criminal cases, forensic science reports and expert testimony playing an increasingly important role in adjudication. Little is known about how judges view their background in forensic scientific evidence, and what type of specialized training they receive on it. Through this paper, the authors have discovered that the judges held views regarding the scientific support for different forensic science disciplines that were consistent with valuable literature, their error rate estimates were more supported by research than many estimates by laypersons, who often assume forensic methods are nearly infallible. The paper reveals that the training corresponded with judge's views that they should, and do take on a more active gatekeeping role regarding forensics. Regarding the tools, judges need to vet forensic experts and properly evaluate forensic science education needs. Judges reported needs in accessing better material concerning the reliability of forensic science methods. These results support new efforts to expand scientific evidence education in the judiciary.

Douglas H. Ubelaker in his book **"Forensic Science: Current Issues, Future Directions" (2012)** presents a comprehensive international discussion of key issues and future directions within the forensic sciences. The book examines central issues within each discipline, provides perspective on current debate and explores current and proposed research initiatives.

Anthony J Bertino in his book **"Forensic Science: Fundamentals and Investigations 2012 Update" 2011** has revealed that due to the prevalence of contemporary television shows focusing on criminal justice and crime scene investigation, as well as the increasing popularity of detective films and literature, many students are now very interested in delving into the field of forensic science. Channel your enthusiasm into a lucrative educational opportunity with the aid of the cutting-edge, recently updated Forensic Science: Fundamentals and

Investigations, 2012 Update. This work has been meticulously designed to provide accurate scientific information and an effective methodology that is tailored to meet the requirements of your high school course.

It takes a hands-on approach to learning and focuses on how science is used in the field of forensics. The student resources integrate mathematics, chemistry, biology, physics, and earth science, aligning their content with the National Science Education Standards, which are clearly indicated by icons. This book combines in-depth scientific principles with practical classroom and laboratory exercises, readings, captivating case studies, and scenarios at the beginning of each chapter. The book offers immediate access to a vast array of articles and online materials that captivate the curiosity of contemporary high school students. The revised version has 10 additional capstone projects that synthesize the principles acquired throughout the curriculum. Our teacher assistance and lab activities provide a thorough and efficient way to guarantee that students obtain a well-rounded scientific education. This approach keeps students of all learning levels engaged and excited about science.

Jim Fraser in his book "**Forensic Science: A Very Short Introduction" (2010)** has addressed various questions like what happens at a crime scene? How does DNA profiling work? How can it help solve crimes that happened 20 years ago? In this Very Short Introduction, Jim Fraser introduces the concept of forensic science and explains how it is used in the investigation of crime. The book begins at the crime scene itself, explaining the principles and processes of crime scene management. It explores how forensic scientists work; from the reconstruction of events to laboratory examinations. The book highlights the techniques they use, such as fingerprinting, and goes on to highlight the immense impact DNA profiling has had.

Kelly Pyrek in his book **"Forensic Science under Siege: The Challenges of Forensic Laboratories and the Medico-Legal Investigation System" (2007)** has

highlighted the fact that Forensic science laboratory reputations have increasingly come under fire. Incidents of tainted evidence, false reports, allegations of negligence, scientifically flawed testimony, or - worse yet - perjury in in-court testimony, have all served to cast a shadow over the forensic sciences. The author of this book tries to integrate and explain these problematic trends in forensic science. The book examines these challenges, while also exploring possible solutions (such as the formation of a forensic science consortium to address specific legislative issues). The book provides insight on the current state of forensic science, demands, and future direction as provided by leading experts in the field consolidates the current state of standards and best-practices of labs across disciplines discusses a controversial topic that must be addressed for political support and financial funding of forensic science to improve.

Editor Peter C. White in the edited publication of the book **"Crime Scene to Court: The Essentials of Forensic Science" (2004)** covers all three main areas of an investigation where forensic science is practiced, namely the scene of the crime, the forensic laboratory and the court. The book includes details of how crime scene and forensic examinations are conducted, the principles of crime scene investigations and the importance of this work in an investigation, and courtroom procedures and the role of the expert witness. The latest methods and techniques used in crime scene investigation and forensic laboratories are reported, cases are presented to illustrate why and how examinations are performed to generate forensic evidence. The author also highlights changes in professional requirements, and the latest developments in DNA.

B. Articles: -

Brandon L. Garrett et al., *Judges and forensic science education: A national survey*, 321 J. Forensic Science International, 110714 (2021). This paper discusses criminal cases, forensic science reports, and expert testimony playing an

increasingly important role in adjudication. Little is known about how judges view their background in forensic scientific evidence, and what type of specialized training they receive on it. Through this paper, the authors have discovered that the judges held views regarding the scientific support for different forensic science disciplines that were consistent with valuable literature, their error rate estimates were more supported by research than many estimates by laypersons, who often assume forensic methods are nearly infallible. The paper reveals that the training corresponded with judge's views that they should, and do take on a more active gatekeeping role regarding forensics. Regarding the tools, judges need to vet forensic experts and properly evaluate forensic science education needs. Judges reported needs in accessing better material concerning the reliability of forensic science methods. These results support new efforts to expand scientific evidence education in the judiciary.

Celine Weyermann et al., ***A different Perspective on the Forensic Science Crisis*****, 323 J. Forensic Science International, 110779 (2021).** This paper attempts to address for conceptualization, increasing fragmentation into separate processes and specializations using a different perspective, through a comparison with established disciplines, namely material science, medicines and historical science. The comparison with material science shows that despite varied organizational and legal models and the interdisciplinary nature of the field, a common element to all forensic science endeavors exists.

Nina Sunde et al., ***A hierarchy of expert performance (HEP) applied to digital forensics: Reliability and biasability in digital forensics decision making*****, 37 J. Forensic Science International: Digital Investigation, (2021).** This paper examines the bias ability (impact of contextual information) and reliability (consistency) of digital forensic observations, interpretations and conclusions, digital forensic.

Thomas Holt et al., ***Exploring digital evidence recognition among front-line law enforcement officers at fatal crash scenes*****, 37 J. Forensic Science International:**

Digital Investigation, (2021). Digital forensic evidence has become an essential component of criminal investigations across the world. The amplified integration of technology with society however continues to present new challenges for law enforcement officers. This paper addressed this problem in the literature by examining a comparative population of respondents from the state police in a large Midwestern and large southern state.

Virginia N.L. Franqueira et al., *Towards Sound Forensic Arguments: Structured Argumentation Applied to Digital Forensics Practice*, 32 J. Forensic Science International: Digital Investigation, (2020). Digital forensic practitioners are increasingly facing examinations, which are both complex in nature and structure. This paper proposes the use of 'Structured Augmentation' as a valuable and flexible ingredient of the practitioner thinking toolbox. It explores this approach using examples, which allow discussion of the benefits and application of structured augmentation to real-world contexts.

Litao Wang et al., A *knowledge-based reasoning model for crime reconstruction and investigation*, 159 J. Expert Systems with Applications, (2020). Artificial Intelligence has been successfully applied in many areas including forensic sciences. Perhaps all forensic work can be regarded as helping reconstruct crimes, i.e. clarify the sequence of the events that took place in the commission of a crime through evidence. However, there are little researches on crime reconstruction using artificial intelligence methods. This paper presents a model, which is termed a case type-based model, based on the knowledge of a type of crime.

Timothy Bollé et al., *The role of evaluations in reaching decisions using automated systems supporting forensic analysis*, 34 J. Forensic Science International: Digital Investigation, (2020). Automated systems allow forensic practitioners to perform analysis tasks that would otherwise be infeasible. However, unless the outputs of such systems are critically evaluated using a scientifically based framework, there is a risk of undetected errors or bias resulting in wrong decisions. This work presents a framework based on the principles of

scientific interpretation, and provides an evaluation hierarchy for automated systems, including machine learning approaches, to strengthen forensic conclusions**.**

Eoghan Casey et al., *Standardization of file recovery classification and authentication*, 31 J. Digital Investigation, (2019). Digital forensic can no longer tolerate soft that cannot be relied upon to perform specific functions such as file recovery. Indistinct and non-standardized results increase the risk of misinterpretation by digital forensic practitioners and hinder automated correlation of file recovery results in forensic analysis and tool testing. This paper applies the core forensic processes of classification, authentication and evaluation of file recovery. Especially this paper defines a vocabulary for software developers, testers and practitioners to classify, authenticate, evaluate and present results of file recovery operations.

Glinda S. Cooper, et al., *Cognitive bias research in forensic science: A systematic review*, 297 J. Forensic Science International, 35-46 (2019). The extent to which cognitive biases may influence decision-making in forensic science is an important question with implications for training and practices. This set of studies provides a robust database, with evidence of the influence of confirmation bias on analyst's conclusions, especially among the studies with practitioners and trainees presented with case-specific information about the suspect or crime. The available research supports the idea of the susceptibility of forensic science practitioners to various types of confirmation bias.

has introduced the field of forensic semiotics as a tool for understanding crime and criminality. It focuses on how symbolism, ritual, and other sign-based activities play a crucial role in the constitution of criminal organizations and often in the enactment of individual crimes. The book presents semiotic notions, methods, and techniques that can be applied to forensic science

Nina Sunde, et al., *Cognitive and human factors in digital forensics: Problems, challenges, and the way forward,* 29 J. Digital Investigation, 101-108 (2019).

Digital forensic is an important and growing forensic domain. Research on injustices and misleading evidence, as well as various inquiries in the UK and the US, have highlighted human error as an issue within Forensic Science. This has led to increased attention to the sources of cognitive bias and potential countermeasures within many forensic disciplines. The main goal of this article is to contribute to a more scientifically sound digital forensics domain by addressing the issues of cognitive bias as a source of error. In the paper, an analysis of seven sources of cognitive and human error especially within the digital forensics process and discussion relevant to countermeasure is been done.

Craig Adam in the book **"Forensic Evidence in Court: Evaluation and Scientific Opinion" (2016).** Has aimed to provide a thorough and detailed discussion of the principles and practice of evidence interpretation and evaluation by using real cases by way of illustration. The book describes and debates the issues around the admissibility and reliability of scientific evidence presented to the court. It also highlights, the principles underpinning interpretation and evaluation, including discussion of formal statistical methods.

Gary Edmond et al., *Cinderella Story? The Social Production of a Forensic "Science",* 106 J. The Journal of Criminal Law and Criminology, 219-273 (2016). The last decade has witnessed unprecedented criticism of the forensic sciences from academic commentators and authoritative scientific and technical organizations. Simultaneously, podiatrists have begun to promote themselves as forensic scientists, capable of assisting investigators and courts in their endeavors to identify offenders. This article traces the emergence of forensic podiatry, particularly forensic gait analysis. Forensic gait analysis is a practice that involves comparing persons of interest in crime-related images (such as CCTV and surveillance recordings) with reference images of suspects, where the primary focus is on movement and posture.

Ate Kloosterman et al., *The interface between forensic science and technology: how technology could cause a paradigm shift in the role of forensic institutes in*

***the criminal justice system*, 370 J. Philosophical Transactions: Biological Sciences, 1-10 (2015).** In this paper, the importance of modern technology in forensic investigations issue 'The paradigm shift for forensic is discussed. Recent technological developments are creating new possibilities, to perform robust scientific measurements and studies outside the controlled science. The paper analyses that, on-site forensic investigations are manifold and such technology has the potential to strongly increase the speed and efficacy of the criminal justice system. However, such genetic benefits are only realized when quality can be guaranteed at all times and findings can be used as forensic evidence in court.

Eadaoin O'Brien et al., *Science in the court: pitfalls, challenges and solutions*, 370 J. Philosophical Transactions: Biological Sciences, 1-7 (2015). The paper expresses that number of high-profile reports and a growing body of literature questions and critically reflects on core issues about the methodologies informing forensic science and their effective use within the criminal justice system.

Jessica D. Gabel, *Realizing Reliability in Forensic Science from the Ground Up*, 104 J. The Journal of Criminal Law and Criminology 283, 283-352 (2014). This Article emphasizes that forensic flaws persist and that deficiencies in forensic science have harrowing implications for criminal justice. In the wake of numerous calls for forensic reform, the paper proposes the use of existing models and frameworks already in place to improve the quality and cost of the forensic science program, rather than creating an entirely new and unaffordable system. At the bottom, this Article calls for collaboration between crime labs, universities and research centers, and the criminal justice system to make forensic science more reliable.

Ian Burneyet al., *Making space for criminalistics: Hans Gross and fin-de-siècle CSI*, 44 J. Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences 16, 16-25 (2013). This article explores the articulation of a novel forensic object the ‘crime scene’ and its corresponding expert- the investigating officer. The paper emphasizes the

material, physical, psychological and instrumental means through which the crime scene as a delineated space, and its investigator as a disciplined agent operating within it, jointly came into being.

Paul Roberts, *Science in the Criminal Process*, 14 J. Oxford Journal of Legal Studies 469, 469-506 (1994). This paper discusses sufficient parallels between science and law, their institutions, practices and ideologies, the paper explains how Forensic science makes an important and ever-expanding contribution to the investigation of crime and the successful prosecution of offenders, but at the same time causes notorious injustices.

C. Statutes and Bills

a) The Indian Evidence Act 1872 (now The Bharatiya Sakshya Adhiniyan 2023)

b) The Indian Penal Code 1860 (now The Bharatiya Nyaya Sanhita, 2023)

c) Code of Criminal Procedure 1973 (now The Bharatiya Nagarik Suraksha Sanhita 2023)

d) Identification of Prisoners Act, 1920

e) Information Technology Act, 2000

f) Digital Personal Data Protection Act, 2023

g) The Constitution of India, 1950

h) The DNA Technology (Use and Application) Regulation Bill, 2019.

The Bharatiya Nagarik Suraksha Sanhita 2023

The Bharatiya Nagarik Suraksha Sanhita, 2023) (BNSS) aims to replace the Criminal Procedure Code, 1973 (CrPC). The BNSS outlines the process for arrest, prosecution, and bail.

BNSS requires a thorough forensic examination for crimes that carry a minimum sentence of seven years or more. Forensic experts are dispatched to crime scenes to meticulously gather forensic evidence and carefully document the entire process.

Gathering forensic evidence in severe offences is now a requirement in order to improve the quality of investigations and increase the likelihood of successful

convictions. This nationwide implementation strengthens states by enhancing infrastructure. In addition, the growing number of samples being collected and the granting of expert exemptions are enhancing forensic processes.

Legal Provisions

Section 176(3)

This section requires the gathering of forensic evidence at the crime scene by a qualified expert for offences that carry a prison sentence of seven years or longer. The provision sets forth a five-year timeframe for implementation.

Section 329

Section 329 now permits government scientific experts to submit reports in court without the need for oral testimony, broadening the range of exempted experts. BNSS includes government scientific experts and also expands its scope of application to any other scientific expert specified or certified by the state or central government. The act enables a wider array of scientific experts to participate in legal processes.

Section 330

In BNSS, every document that is filed must have its details included in a list. The prosecution or indicted, along with their legal representatives, must confirm or refute the authenticity of each document within a thirty-day period after receiving them. The Court has the authority to extend the time limit if deemed necessary, and an expert cannot be summoned unless there is a dispute regarding their report. Section 330 of BNSS describes a comparable procedure for managing court documents, which involves determining their authenticity. The act includes a requirement for a specified timeframe for making a decision on admission or denial, as well as a provision related to expert reports.

Section 349

Section 349 broadens the authority of Magistrates to issue written orders for the collection of forensic samples, such as fingerprints and voice samples, from

individuals. Section 349 of the BNSS grants first-class Magistrates the authority to order the collection of samples for investigative purposes. The act provides a wider range of options, such as finger impressions and voice samples. It is worth mentioning that BNSS offers the convenience of gathering samples without the need for prior arrest, allowing for greater flexibility.

Bharartiya Sakshya Adhiniyam 2023

The Indian Evidence Act of 1872 is replaced by the Bharatiya Sakshya Adhiniyam, 2023.

Section 2(1) d

According to the Indian Evidence Act (IEA), various forms of illustrations such as writings, maps, and caricatures are considered as documents. The Bharatiya Sakshya Adhiniyam (BSA) states that electronic records will also be recognised as documents. Documentary evidence consists of primary and secondary evidence. Primary evidence consists of the original document and its components, such as electronic records and video recordings. Secondary evidence consists of various types of documentation and oral testimonies that can provide support for the information found in the original source. This classification is maintained by the BSA.

2(1) (e) (i)

Electronic submission of oral evidence is permitted by the BSA. This would allow witnesses, accused individuals, and victims to provide testimony using electronic methods.

Section 61

Documentary evidence encompasses information contained within electronic records that have been printed or stored in optical or magnetic media generated by a computer. It is possible that this information has been stored or processed by a variety of computers or multiple computer systems. The BSA states that electronic

or digital records hold the same legal weight as paper records. It broadens the scope of electronic records to encompass data stored in semiconductor memory or any communication devices such as smartphones and laptops. This will also encompass data pertaining to emails, server logs, smartphones, locational evidence, and voice mails.

D. Commission and Committee Report

a) Gore Committee on Police Training, 1971.

The Gore Committee was established by the Government of India, as per the Ministry of Home Affairs Resolution No. 9/72/71-Pers. II dated November 10, 1971.The Committee was tasked with conducting a thorough evaluation of the current police training programs in the country and proposing necessary modifications to ensure that the country has a highly skilled and capable police force that can effectively adapt to the evolving social landscape.

The committee suggested that the growing integration of science and technology into police work will require a significant number of scientific and technical personnel to staff various departments within the police force. These departments include information systems, wireless and electronic branches, forensic science laboratories, and automobile or transport and armament sections. Thorough plans will be necessary for the training of technical personnel from different backgrounds in handling and utilization of scientific equipment. It was also suggested by the committee that it would be beneficial for them to receive some fundamental training in police work. The complete details of courses for such individuals should be determined through collaboration with the relevant experts.

The demand for technical personnel is expected to be highest in the electronics field, particularly in computer technology. While the training for lower-level staff will be the responsibility of the states, a separate institution may need to be established by the Central Government to provide training for the higher-ranking officers in the wireless and electronics branches of the police forces. The Institute of Criminology and Forensic Science should consider expanding its course

offerings to encompass a wider range of branches within the field of forensic science.

It is crucial for governments to allocate sufficient resources towards research and development in order to facilitate the integration of science and technology into police operations in India.

b) Malimath Committee on Reforms of Criminal Justice System, Government of India, Ministry of Home Affairs, 2002.

The Government of India, Ministry of Home Affairs established the Malimath Committee on Reforms of the Criminal Justice System on 24 November 2000. The committee's purpose was to examine ways to improve and modernise the Criminal Justice System. The Committee was formed under the leadership of Justice V.S. Malimath, who has an extensive background in the legal field. The committee opined that there is no denying that the use of forensic science in crime investigation should start from the initial visit of the investigating officer to the crime scene. This is important to ensure that all pertinent physical hints, which include trace evidence, are correctly recognised and gathered for future forensic examination. This may be most effectively achieved by having the investigating officer (IO) escorted to the crime site by a scientifically qualified individual. In most sophisticated nations, it is customary to have scientific experts, known by different titles such as 'Field Criminalists', 'Scene of Crime Officers' (SOCO), or Police Scientists, as regular members of each police station. These professionals are picked either from a scientific cadre or from the police force itself, with a specific focus on those who possess both a talent for scientific work and an academic foundation in science disciplines.

These individuals get comprehensive training in crime scene management and the recognition of various scientific evidence relevant to different sorts of crimes. The committee revealed that the current use of forensic science in crime investigation is rather low in the nation, with approximately 5-6% of the recorded crime cases being submitted to the Forensic Science Laboratories (FSLs) and Fingerprint

Bureau combined. It was therefore suggested by the committee that there is a pressing need to significantly improve the current situation, especially considering the persistent decline in conviction rates in the nation over the years. The use of conclusive forensic evidence may help partially reverse this trend.

c) Padmanabhaiah Committee, 2000.

The Padmanabhaiah Committee on Police Reforms was formed by the Ministry of Home Affairs, Government of India in January 2000. The Committee included of four members, all of whom were policemen - two retired and two still serving. Additionally, the Chairman of the Committee was a former Union Home Secretary. The Committee lacked representation from other sectors of society or the general public. The Committee delivered the findings to the central government in October 2000. The Committee acknowledges the increasing trend of politicisation and criminalization within the police force.

The Committee states that corruption is the underlying reason for the politicisation and criminalization of the police. If the concept of "corruption" had been understood more broadly, encompassing the erosion of public standards and principles that impact society and organisations, this evaluation might have been more widely embraced. However, the suggestions put forth by the Committee to address the rising tide of criminalization clearly indicate a different intention. These suggestions involve enhancing the reputation of the constabulary and enhancing their service and standard of living. Additionally, a new Departmental Inquiry Manual and Code of Conduct for the police should be developed. It is also recommended that property returns be filed by both gazetted and non-gazetted police officers. Furthermore, internal vigilance within the police department should be improved, and police officers should be more accessible to the public. Lastly, a review of the arrest records made by the police station staff is advised.

d) Police Act Drafting Committee, 2005.

The Government of India established a Committee in September 2005 with the task of drafting a new Police Act to replace the outdated Police Act of 1861. The Committee has been assigned the duty of drafting a new Police Act, considering the evolving function and obstacles faced by the police force, particularly due to the increasing presence of insurgency, militancy, and naxalism. The committee proposed to incorporate measures to promote a positive mindset among police officers, involving adopting effective methods to encourage collaboration and backing from the community. Additionally, the new Police Act should align with the demands of the public in a modern democratic society. It is crucial to integrate scientific inquiry methods into the criminal justice system to empower the police in addressing emerging patterns of crime, such as cybercrime and the use of advanced technology by criminals. These measures should be appropriately included in the new Act.

e) Ribeiro Committee on Police Reforms (1998).

The Ministry of Home Affairs, Government of India, has established Ribeiro Committee on Police Reforms in response to the Supreme Court's recommendations given in relation to Writ Petition (Civil) No. 310 of 1996. The Committee is composed of four members, with the Chairperson leading the group. Over a brief period, the Committee has made multiple suggestions. The Committee indicates that this should not be seen as an attempt to replace the judgement of the individuals who played a crucial role in making highly insightful and valuable suggestions. If their intentions are to be achieved, their objectives acquired, and their goal realized, then some compromises and adjustments must be made in the interest of the public.

We have a different perspective. The current state of the police system in this country has been shaped by various compromises and adjustments that were deemed necessary to implement police reforms. Arrangements have been made in favour of private interests rather than public ones. It is worth noting that police reforms in this country have faced significant obstacles from three key groups:

politicians, bureaucrats, and, in some instances, the police officers themselves. Measures for police reforms should always be determined independently, without being influenced by the response of any particular pressure groups. The police force is an integral part of the community, and it is crucial that the interests of the community drive the efforts for police reforms in the country.

f) The National Police Commission (NPC) 1977-81

The National Police Commission (NPC) was established by the Government of India in 1977 with a broad mandate to address various aspects of the police organizational structure. This includes its role, functions, accountability, relations with the public, political interference, misuse of powers, and evaluation of performance. This was the initial Commission established at the national level following Independence. The Commission generated eight reports from 1979 to 1981, proposing comprehensive reforms in the current police structure. As per the NPC, it is crucial to establish an inquiry process for addressing grievances against the police that is perceived as fair and just by both the police force and the public. The Commission therefore proposed provisions that would involve investigations carried out by departmental authorities as well as an independent authority separate from the police. The Commission believed that it was necessary for the supervisory ranks within the police hierarchy to thoroughly investigate and resolve the numerous complaints against the police. It was also recommended that training institutions should focus on developing scientific inquiry strategies and providing efficient guidance to trainees in this area.

1.7.Research Method

The methodology adopted for the present study is doctrinal. The nature of research involves an examination of the relevance of forensic science in the administration of criminal justice. The researcher has based her study on the method of comprehensive analytical understanding of the other scholar in a similar subject. The research methodology adopted for this research has required the gathering of significant resources, which includes journals, articles, textbooks, internet sources,

e-books. The researcher has further made use of sources including reports and recommendations of various committees.

The citation method used is APA style. The researcher has gathered materials from various sources available at the UPES Library and UPES online e-resources database. For this mentioned reason, the Researcher has analysed the scholarly articles, books, legislative provisions, decided case laws, reports, and recommendations of various committees.

1.8.Hypothesis

The present research based on a study of literature will analyze and assess the significance of Forensic Science in Criminal Investigation. The hypothesis proposed for this research is

1. **The absence of comprehensive regulation and effective mechanisms undermines the relevance and applicability of forensic science disrupting the timely and infallible administration of criminal justice in India.**
2. **Lack of synergy between the judiciary, investigating agencies and criminalists results in miscarriage of justice.**

1.9.Significance of Research

The research is intended to bridge up the gap that exists in the disciple of forensic science and the criminal justice delivery system. The research helps provide a better understanding of the importance of forensic science in criminal investigations. The research will help in developing a clear idea as to how the evidence furnished by the forensic labs is scrutinized and verified. The paper further highlights and recommends suggestions pertaining to the noticeable differences in the forensic science procedures used by different law enforcement authorities and organizations at the Union, state, and municipal levels. This is applicable when it comes to distributing financial resources, providing analytical instruments, having highly

skilled and knowledgeable people, achieving recognition and certification, and implementing strict supervision methods.

The research uses case studies to highlight instances of mishandling or improper interpretation of evidence and laboratory tests, as well as the existence of scientific evidence that may create a deceptive impression of significance. It demonstrates the serious ramifications that these issues may have. Moreover, the research examines the possibility of bias, inefficiency, or inadequate internal controls among forensic experts and their facilities.

The study provides a deeper understanding of how professionals in the field of forensic science and the evidence they gather play a crucial role in ensuring justice is served within the criminal justice system. The research explores profound inquiries that form the basis for the legal recognition and use of forensic evidence in criminal proceedings.

The research emphasizes the importance of imparting forensic teachings to law students at the graduate level so that it helps them to have a better understanding of this discipline. Science has started to invade and affect the various aspects of crime. Criminals nowadays are much smarter than investigators and hence it becomes important that forensic scientists develop new and improvised techniques to detect crime and criminals. This research is significant in identifying the expertise and skills necessary for effective and speedy processing of crime.

1.10. Limitations of the Study and Novelty of the Outcome

Forensic discipline is growing and expanding in different new fields by designing new techniques and procedures, which was almost unknown to the world a decade back. The research is limited to the study of forensic studies that are related to collection, identification, recognition, comparison and analysis of evidence gathered from the scene of a crime. Forensic Toxicology, DNA profiling, and Forensic Psychology entail pertinent areas of information, scientific knowledge, and operations in the investigation and enforcement of laws therefore these domains are covered in detail in the research work.

1.11. Research Gap

The 20th century has been called the age of science in which there have been tremendous scientific and technological developments. However, the study of Forensic Science is still in its infancy stage in India and has been treated as a Cinderella child by the Government of India. There is a dearth of research in this field and not much study has been carried out by the scholars in this domain. There is a lot of ambiguity regarding the relevance of forensic science in the administration of criminal justice system in India. When looked into the Indian Forensic scenario carefully, there are several shortcomings and pitfalls which need to be addressed and researched for better understanding. Due to dearth of study in forensic science people are not aware and sensitized about the importance, and contribution of forensic science in criminal justice system. As stated above, the Indian forensic system is in dire need of a thorough and detailed study. Not much is known about the application and admissibility of forensic science. The research highlights the need for capacity building of Forensics in India if early effective justice is to be provided to the common man in the country. The role of Judges in interpreting forensic evidence is quite unknown as they themselves are not equipped with the various forensic processes and technologies. The study helps to ascertain and highlight the use and application of forensic science in the criminal investigation of cases. The study also addresses the challenges related to the admissibility and authenticity of forensic evidence in courts in India. The study analyzes the ways of building synergy between the judiciary, investigative agencies and criminalists

CHAPTER II
INTRODUCTION TO FORENSIC SCIENCE AND ITS DISCIPLINES

"*Whenever he steps, whatever he touches, whatever he leaves, even unconsciously, will serve as a silent witness against him."*(Mistek et al., 2019)

Edmond Locard

1. Introduction

Forensic science is considered to be a science used along with the law in a fair and just settlement of disputes. It is an important handmaiden of law expected to assist with the resolution of conflicts.(Forensic Fraud: Evaluating Law Enforcement and Forensic Science Cultures in ... - Brent E. Turvey

Forensic Science is generally the application of scientific processes, information, knowledge, rules and principles to reach out to the solution for legal questions.

Three decades ago, forensic investigation was considered to be religiously a multi branched study that could with the help of rigorous practice, patience, easily trace and determine the accused beyond reasonable doubts. The capabilities of forensic criminalist to resolve a case were undoubtedly believed and subsequently forensic science began to be frequently used in criminal investigations.(Hahn et al., 2018)

The *Oxford English Dictionary* describes "*forensic science*" as a "*mixed science*". The early use of forensic science was somewhat in a mixed manner when science was applied to the ambiguous questions for catering justice in the court. Forensic science has witnessed tremendous growth and is in a transitional phase.

Considering the use of forensic science in cracking down criminal cases for the interest of the public, it is believed to have a hectic and active future.(Fundamentals of Forensic Science - Max M. Houck, Jay A.

Forensic science exemplifies the scientific mechanism of establishing the links between people, things, places associated with a criminal case.

Like the nomenclature, the discipline can be divided into halves. The word *science* is the accumulation of systematic scientific processes applied to study and analyze the physical world. In the mid of 17th century, as per the *Oxford Dictionary*, the word *forensic* was derived out of Latin word *forum* which was frequently used by the public. The Senate in ancient Rome gathered in a public forum where issues related to politics and policymaking were discussed and deliberated. Teams representing high schools, colleges and universities in debates and public speaking are addressed as Forensic teams even today.

The word Forensic can be interpreted to mean a term related to the public or a matter of legal concern. Together the words *Forensic Science* can be used to refer to a discipline or a branch of science dealing with collection, investigation, interpretation, and analysis of data used by the criminalists to answer the doubts and questions generally faced by the courts. For the public forensic science is no less than a miracle used by police to decipher cold cases that had earlier hindered criminal investigation. It can easily destruct the accused alibi and establish the guilt by simply inspecting a small piece of evidence generally not seen by the naked eyes.(Fundamentals of Forensic Science - Max M. Houck, Jay A. Siegel

The use of scientific methods and processes to solve a case has been practiced since ancient times. But it was only during the twentieth century that forensic science started to be used most rigorously with the emergence of diverse areas like fingerprints comparison, bite marks analysis, arson science, hair comparison. Equipped with these new techniques, the law enforcement investigators were able to understand and undoubtedly accept the science and logic behind the crime and the traces left by the accused at the scene of a crime. These techniques were equally

helpful for the prosecutors in building a case against the accused and ensuring his arrest and conviction. With the emergence of new domains, techniques, and the earnest use of forensic science in criminal investigation, the criminal justice system took on an entirely new dimension. The cases, which were not possible to solve due to the lack of confession and witnesses, are now easily solved.

2. Delineating the term Forensic Science

Various authors to explain the term forensic science have propounded different definitions. Most of the definition emphasizes the staunch connection between law and science but does not delve into the convolution and constraint between these peculiar relationships. Apparently, forensic Science is the assessment, examination, clarification of legal incidence related to the specification, genesis and life history of person, materials (medicines, glass, and threads). The disclosure is done by putting in use various scientific processes.

The need for such an overhaul is the examination of evidence. Forensic science helps to deduce the demeanor, motive, and intention after ascertaining the facts, circumstances, and evidence of a case. Forensic Science is therefore a solution to various problems and queries like when, how, what, why, whom? Explanations to these queries can be made by the identification of the offender and the victim, using scientific techniques like fingerprints, DNA, bloodstain pattern, ballistic forensic, serology.(J. C. Fraser.

Society is growing complex day by day and so are the crimes committed by the criminals. To monitor the behavior and acts of citizens, society highly relies on laws and regulations. Forensic science plays a very important role here as it infuses information and technical knowledge of science into the interpretation and application of such laws. Integration of science with criminal and civil laws is inevitable to maintain peace, tranquility, and security of people in society. For instance, the rules and bodies that check the quality of our food and edibles, the impact and extent of vehicle emissions, the efficacy of drugs, the quality of water that we consume and the detrimental effect of pesticides and insecticides on crops

as well as the health of the humans. Enacting and applying any drug and food rules or having laws concerning the environment and its effective monitoring and application without the help of scientific processes and technologies would be impossible.(*Instructor's Manual For*, 2021)

To tackle the growing and variant nature of crimes it is pertinent that the rules and laws are simultaneously amended and modified. The investigative and law enforcement agencies are highly dependent on forensic criminalists for scientific advice and support. Forensic science plays a very important role in the administration of the criminal justice system in India. The role and ability of criminalists in furnishing authentic and pertinent details relating to the evidence collected at the scene of the crime is extremely important in resolving the case. Forensic science entails different scientific specialties and branches with the assistance of which pieces of evidence are examined to determine and divulge facts concerning the prosecution or defense in legal proceedings.

The analytical results of forensic science may be either exculpatory, inculpatory, or maybe even neutral in ongoing investigations. Great efforts and errorless use of scientific procedures are necessary to avoid bias and discrepancies. The use of Forensic science in the examination and analysis of physical evidence found at the scene of a crime is well accepted as an important part of the criminal investigation. The materials and the traces obtained from the crime scene are inspected and analyzed throughout the investigation and at the later stage during courtroom sessions to ascertain the truth. The criminalists and the interpretive experts help the court to understand how the evidence is related to the case at hand.(Hahn et al., 2018) Forensic science has its own limitations, which are almost known to all the forensic criminalists and experts. To prove its efficacy the methodologies and analysis done by forensic science has to stand up to the test and challenges of the legal system. Forensic methods and techniques should be applied in an impartial and rational manner to maintain the sanctity and purity of the data and information derived from the crime scene.(Hahn et al., 2018)

For the maintenance of law and order there exists a plethora of civil and criminal laws. This has led forensic science as a comprehensive subject making it difficult to narrow its scope and jurisdiction. Therefore, forensic science is an umbrella term enclosing multitudes of occupations wherein the experts use their skill and labor to assist the investigating officers to investigate a crime.

3. Different Disciplines of Forensic Science

The domain of Forensic Science is very vast. It encompasses a very broad ambit of forensic disciplines applying different techniques, processes, methodologies, tools, acceptability. Certain areas of forensic science are carried out in laboratories for example DNA analysis and toxicology. Other branches are based on the interpretation of hints and patterns by experts for example fingerprints, handwriting, bite-marks. Different practitioners including experts and scientists from the field of medicines, biology, Physics, crime investigators, law enforcement officials, laboratory experts form an important part of forensic science study.(Forensic Fraud: Evaluating Law Enforcement and Forensic Science Cultures in ... - Brent E. Turvey.

3.1. Forensic DNA

Forensic DNA testing has been introduced in the mid 1980's(Forensic Application of DNA 'Fingerprints'. Nature.) and since then it has contributed in a great manner to the investigative branch and judicial system of various countries. The emergence of the study of DNA along with the discovery of its structure and the revelation of how it is a reservoir of genetic information has completely changed our understanding of the evolution and development of flora, fauna including other living creatures. Additionally, it has tremendously revolutionized the practice of forensic science.

With the help of DNA profiling, it is now easily possible to link the DNA sample to the suspect with certainty allowing individuality in a specific case. It is a potent identification tool complementing serology, fingerprints, therefore, helping the law enforcement agencies.(Fundamentals of Forensic Science - Max M. Houck, Jay A.

Siegel .) Deoxyibonucleic acid (DNA) is a very important but generally complex molecule present in almost all plants as well as animals. In humans, the red blood cells are exceptions, as it has no nucleus therefore, DNA is not found in this region.

DNA molecules are known as *polymers* and are made up of simpler units *monomers* that are repeated. In a cell, DNA is found in two areas, the mitochondria, and the nucleus. The mitochondrial DNA (mtDNA) is different from that of nucleus DNA in size and shape and is used in a completely different manner for the identification of biologic traces. mtDNA is exclusively inherited from the mother whereas the nucleus DNA is inherited from both mother and father.

3.1.1. Nuclear DNA

The geometrical shape of a nuclear DNA is called double helix. DNA appears like two helices twined together to each other just like a spiral staircase. The poles of the DNA structure are made up of alternate molecules of sugar (deoxyribose and phosphate). Each sugar molecule has one out of four nucleotides, adenine (A), guanine (G), cytosine (C) and thymine (T). With the proximity of thymine and adenine base a bond is formed. Similarly, when cytosine and guanine get close they bond. There cannot be any bonding of A and T with G and C.

These base pairs are connected to sugar phosphate backbones and the linkages that is created must be A-T, T-A, G-C or C-G. Apart from the above rule, the principle of inheritance and genetics determine the sequence of pairing.(Fundamentals of Forensic Science - Max M. Houck, Jay A. Siegel.) The sequence of base pairing forms a genetic code that decides the nature and characteristic of a person. For instance, the mobile numbers consist of 10 digits but in order to get a particular person’s phone ring the number has to be dialed in the correct order.

3.1.2. Cells the Home for DNA

Almost all the cells in the human body consist of nucleus. Through the nucleus, the functions of the cells are regulated. There are 46 structures called chromosomes within the nucleus wherein DNA is arranged. There are 23 pairs of chromosomes.

In each pair, one member is from the father's sperm cells and the other is from the egg cells of mother. There are 23 chromosomes contained each in ovum and sperm. The 23 chromosomes of sperm and egg cell when united are paired into 46 chromosomes available in every cell of the offspring. The sex of the child is determined by one of the 23 pairs of the chromosomes. In case of females, both chromosomes are of the X type. Whereas in males one of the chromosomes is Y and the other one is X type.(Fundamentals of Forensic Science - Max M. Houck, Jay A. Siegel.)

3.1.3. Genetic Code

Within the 46 chromosomes, there lie billions of base pairs. The growth of embryo after conception is managed by certain section base pairs, which are called genes. Genes define the characteristics of all humans. Several genes in concert with each other determine the eye colour, hair colour and other important traits of human. After the successful completion of the Human Genome Project, it has been discovered that there are nearly 30.000 protein-coding genes. These 30,000 genes can produce between 100,000 - 1 million proteins. The purpose of this project is figure out all the genes present on the chromosomes and to study their important functions.(Fundamentals of Forensic Science - Max M. Houck, Jay A. Siegel - Google Books.)

3.1.4. Variations and Locus of Genes

There are two copies of each gene found in an individual. A person gets one copy of gene from the mother and the other one from that father. A single gene finalizes which blood type will be inherited from each parent. There are basically four different blood types A, B, O and AB. Homozygous is a person who gets the same kind of gene from both father and the mother. When a person inherits different kinds of similar genes then he is said to be heterozygous.

A specific gene in the genome at a particular locus is termed as allele. Some of the alleles are dominant and others are of recessive nature. On receiving both dominant and recessive allele from mother and father, the person highlights the dominant

characteristics. With the presence of numerous such alleles, there exists a great chance of variation among humans at this locus. This condition is best for DNA profiling as the variation of alleles at different location can be brought together for the verification of a specific group of alleles in each population.(Fundamentals of Forensic Science - Max M. Houck, Jay A. Siegel - Google Books.)

Restriction fragment length polymorphism (RFLP) is the first DNA profiling procedure to be mostly used by the forensic criminalists This method is no more in use and have been substituted by processes which gives result much faster that too by making use of less Biologic materials. RFLP was gradually replaced by methods carried on through polymerase chain reaction (PCR). This mechanism is applied to enhance the number of DNA by amplification. Presently the techniques that is used in majority of forensic laboratories is known as Short Tandem Repeats. (STRs). STR typing method includes both the features of PCR and RFLP.

3.1.5. How Restriction Fragments Length Polymorphism is carried out

The beginning of DNA profiling was initiated with Restriction Fragments Length Polymorphism (RFLP). In RFLP, DNA is carefully taken from biological materials and reacted with restriction enzymes. This helps to segregate the tiny fragments of DNA known as minisatellites or variable number tandem repeats. The length polymorphism of VNTRs is of 10-100 base pairs. At least 4-6 polymorphic loci are inspected which in turn helps the forensic experts to fetch DNA profiles out of it.

The sequences of the DNA of the target VNTR are already known. With the help of chosen specific enzymes the thread of the DNA is cut at determined base pair order like the ends of the target VNTR. These areas are considered hypervariable as they consist of a huge number of alleles. The first DNA polymorphism best suited for profiling was discovered in the year 1980. This hypervariable gene was known as D14S1. Many other genetic markers were created for RFLP. In the genome, few of the few VNTRs are present only at one location whereas some hypervariable VNTRs are found at the same time at various loci. These are known as multilocus VNTRs.

Despite being highly useful RFLP was not free from defects. The process required double stranded DNA in large numbers and high molecular weight in huge amounts. The samples that are collected from the crime scene at times contain minute quantities of DNA. The samples collected are often of poor state or deteriorated due to varying situation at crime scene or the way it has been stored. Adding to the flaws, the RFLP technique generally involves a long time to examine the samples. Due to the above stated drawbacks, finally, the RFLP technique was abandoned. Although RFLP DNA profiling had great potential to trace the identity and proving the guilt and innocence of a person, but the defects compelled the scientists around the world to look for an improvised DNA profiling mechanism.(Forensic DNA Biology: A Laboratory Manual - Kelly M. Elkins.)

3.1.6. The Polymerase Chain Reaction

In the year 1980, one of the important breakthroughs was the build-out of Polymerase Chain Reaction for forensic application. One of the major problems faced by the scientist community with RFLM was the requirement of large number of samples. This shortcoming was resolved with the development of PCR.(Fundamentals of Forensic Science - Max M. Houck, Jay A. Siegel.) It was now possible for the DNA examiner to do the examination of genetic attribute by applying meager quantity of DNA.(Forensic DNA Biology: A Laboratory Manual - Kelly M. Elkins.) In 1993 Dr. Kary Mullis was awarded Nobel Prize for developing a strategy to apply extremely high temperatures to self-operate polymerase chain reaction for augmentation of DNA.

The whole purpose of the research done by Mullis was to invent a mechanism for the multiplication of DNA artificially by utilizing an enzyme known as DNA polymerase by way of incessant cycles of cold and heat. The PCR process is highly prone to pollution by unfamiliar and external DNA. Great caution is expected to be exercised during the process. A physically secluded position is chosen for the derivation of DNA, which is isolated from the location where the augmentation of the DNA is carried on. The equipment used for PCR operation is known as thermal

cycler. This apparatus is equipped to maintain the required temperature required for the amplification. There are three different steps involved in the PCR technique. a) Denaturation b) Annealing and c) Extension. A reaction emollient, which is a solution of salt buffered at the maximum pH for polymerase enzyme, is added to the DNA samples. The four different DNA nucleotides adenine (A), guanine (G), cytosine (C), and thymine (T) are mixed to the solution. The polymerase enzymes act as catalyst and cause the reaction. Different DNA polymerase is used in PCR, *Taq* is the most used one in PCR.

The reaction results in the division of two strands of DNA forming four separate stands. Further, the stands are put through steps like extension and annealing for the amplification of strands. The continuation of the reaction is allowed until the desired quantity of DNA is obtained. 28 - 32 rounds produce nearly one billion replica versions of DNA, which is enough for the examination, which takes almost 3 hours.

3.1.7. Short Tandem Repeats

A repeating element comprising of 2-6 base pairs was designed in 1980s. This technique is known as Short Tandem Repeats (STRs). to the examination of genetic attributes by applying meager quantity of DNA. STR was undoubtedly a better option over other processes. STR minimized the expense as well as time for DNA examination. The analysis earlier required 7-8 weeks which was lessened to 1 OR at the most 2 days. This technique has the capacity to analyze single strand DNA. Even degraded DNA samples can be used for evaluation.

At a definite temperature and humidity, the scientists are able to coordinate the size of the fragments with the internal standards and superior ladders. The mutation of STR IS 1 in 1000. The occurrence of the STR loci in a genome is once per every 15000 bases. Alleles are the number of repeated STR at a particular locus. Analysts have ascertained that it is possible to differentiate genotypes to one in trillions by simply examining the number of tandem repeats at each of 13 STR loci. The STRs typing is used for the determination of sex using bi-allelic loci on X and Y-

chromosomes, maternity and paternity testing, cases related to sexual assault, and to identify the family traces through familial typing.(Forensic DNA Biology: A Laboratory Manual - Kelly M. Elkins - Google Books.)

3.2. Forensic Toxicology

3.2.1. Introduction

Mostly the first thing that comes to our mind when we hear the word toxicology is poison. Much more is attributed to the meaning of the term. Toxicology involves the study of any unpalatable substance consumed by any living being. The study is simply not limited to knowing the quantity of substance consumed but also delves into its psychological and physiological impacts on living organisms. The application of forensic toxicology is in cases where a person dies in dubious and skeptical conditions.

Forensic pathologist and toxicologist collaborate to ascertain the reason and modus operandi for the commission of death. Forensic toxicologists are also engaged in certain cases where death is not the probable result of consumption of drug. Such cases related to drugged and drunk driving. Forensic toxicologist in these cases finds out the quantity of drugs and alcohol in the body of the accused and its effect on the person's ability to drive a vehicle.

3.2.2. Forensic Pharmacology

The branch of science that deals with the relation between the living organism and drugs is called pharmacology. This branch is further divided into different domains. Clinical Pharmacology is the domain which is generally applicable to forensic science. Clinical Pharmacology studies the adverse effect of drugs on humans and is known as Toxicology. Scientists equipped and train to deal with incidents of death and injury related to drugs and poisons are known as forensic toxicologist.(Baselt.)

There has been a surge in deliberate and accidental death due to drugs operation. Despite rigorous efforts made by the law agencies and administration to regulate the sale and purchase of illicit drugs, its distribution has however remained

uncontrolled. This has led to a universal menace threating the lives and property of people.(Drugs and Human Performance Fact Sheets.) The responsibilities entrusted upon a toxicologist includes(A. W. Jones.)

a) Identification of toxin and drugs in the body of a person
b) Determination of the amount of toxin and drugs.
c) Analyze the reaction and impact of drugs in the body.
d) Go through the history of addiction, duration, and use of the drugs by the person.
e) Identify the metabolites of the drugs consumed.

The study of the toxicologist extends to the matter related to the contravention of the rules and statutes.

3.2.3. Accumulation and Conservation of Toxicology Evidence

Based on the inputs furnished by the medical officer, police personnel attending the body, the toxicologist prepares its report. The medical officer finalizes the sample from the dead body to be sent to the toxicologist for evaluation. Things are quite different in the cases of a living person who is drugged and intoxicated. Samples of blood and urine are collected from the person and submitted for analysis.(Levine & Kerrigan, 2020) Minimum 10 cubic centimeter (cc) of blood is required to carry out an exhaustive toxicological analysis for poisons and drugs. However, a test to determine the intake of alcohol requires less quantity of blood approximately 50 cc.

3.2.4. Methods opted for Toxicological Analysis

An appropriate analytical mechanism needs to be designed by the toxicologist for segregation and ascertainment of drugs and toxics.

3.2.4.1. Collection of Samples

The identification of drugs after it has been consumed and carried to different parts of the body is quite difficult. Having no clue about the drug or the quantity, or at what time the drug was ingested makes the systematic and investigative implementation of schemes strenuous. Certain drugs are very efficacious even if consumed in small quantity and once spread to different parts its accumulation is

extremely low. Few drugs prefer certain organs or cells therefore detection of it becomes very hard. The identification of drugs includes series of pertinent procedures. Below are the few steps involved-

The state of the body and also the area where the drug is more likely to accumulate determines the type of samples extracted for the detection of the drugs in the body. Blood, urine, and hair samples are preferred in case the person is alive. In cases where the person is dead, then all the samples can be utilized for the detection of the drugs. If the person dies immediately after the consumption of drugs, then from stomach, undigested drugs can be easily extracted for analysis.

Urine samples are generally preferred over blood because the accumulation of drugs is much higher. However, blood samples help to establish the presence of drugs and its concentration.(Fundamentals of Forensic Science - Max M. Houck, Jay A. Siegel The use of hair as samples of forensic toxicology has exponentially increased in the last few years. The contributing factor is the quality of hair to retain the drugs for a longer time i.e., as long as it remains attached to the body.

3.2.4.2. Extraction of Drugs from the Samples

Immediately after the collection of the samples the drugs must be segregated. This is to ensure the purity of the drugs so that there is no contamination, and the entire analysis is carried out efficiently.

3.2.4.3. Extraction through Liquid Stage

There are many ways through which the extraction of drugs is carried out effectively. The selection of the method is dependent on the drug and the samples collected. The information pertaining to the pH value of the drugs is very important for the effective separation. Generally, the drugs are either basic or acidic in water solution and few are neutral as well. The pH value of an acidic drug is between 1-7, 7-14 is the range of pH value of basic drugs.

Hydrogen ions are released by an acid element and contrary to it hydrogen ions that are released by acid compounds are easily gained by the base compounds. Water being neutral is neither acidic nor basic. The pH value of water is 7. With an

addition of acidic compound e.g., hydrochloric acid in aqueous solution hydrogen ions is gained, which results in decrease of pH value, making the water more acidic. Likewise, when in a water solution, basic compounds like sodium hydroxide are added in water hydrogen ions is released, turning the water solution basic thus increasing the pH value. When the samples including blood or urine is added to the aqueous solution

with controlled pH value, drugs get easily extracted from the solution. For example, in an acidic aqua solution with pH value less than 7, acidic compounds can be conveniently segregated with the help of chloroform an organic solution. Likewise, from a basic aqueous solution basic drug can be easily extracted by using natural catalyst. This technique is highly beneficial and enables the toxicologist to easily extract and classify the drugs.(Criminalistics: An Introduction to Forensic Science:....) However, in situations where two or more acidic or basic compounds are known to be present, liquid phase extraction is not an appropriate approach. This is because all the acidic or basic drugs will be extracted at the same time and cannot be distinguished using this technique.(*Criminalistics: An Introduction to Forensic Science:...* - *Google Scholar*, n.d.)

3.2.4.4. Extraction through Solid Stage

Solid phase extraction of pharmaceuticals has gained popularity recently to boost sensitivity and circumvent the limitations of liquid phase extraction. In solid phase extraction, the drug is removed from the urine or blood using a tiny column or coated wire. A unique solid matrix is pumped through the blood or urine to remove the drug present. The medication is then removed from the matrix via washing or elution for further examination. Solid phase microextraction (SPME) is a more modern improvement on solid phase extraction as it is the best technique when there are few accessible samples since it can detect and measure extremely minute levels of drug.

3.2.4.5. Screening Test

To determine the presence of drugs in bodily fluids a pilot test is carried out which is known as screening test. This test is conducted to provide a preliminary result that suggests that a drug could be present, but it does not provide a definitive answer. In situations when it is unknown what substance or drugs have been consumed, screening tests are crucial. The test includes the use of drug panels, which typically consists of the substances that are most often misused. The identification of a substance that has allegedly been consumed may also be attempted using these techniques. The two main types of screening tests are chromatographic and immunoassay. Thin-layer chromatography or gas chromatography are typically used in chromatographic testing.

Techniques for immunoassay make use of the interaction that occurs in human blood between antigens and antibodies. An antigen is found both in the blood plasma and on red blood cells. When a bacteria or virus invades the body, it behaves like a foreign antigen and triggers the immune system to create antibodies that can target and paralyze the antigen before it can do damage.

The antibodies that are generated are particular against the antigens inserted in the body. This antigen/antibody response is used in forensic toxicology to identify extremely minute amounts of drugs. Immunoassay methods for drug screening have the significant benefit of not requiring previous drug extraction from urine. Enzyme Multiplied Immunoassay Test (EMIT) is one of the renowned immunoassay tests currently used for extraction of drugs.(Peters et al., 2018)

3.2.4.6. Confirmation of the Presence of the Drugs

Any substances that show up in a screening test must then be verified to be there. In forensic toxicology, mass spectrometry is the only approach that is recognized for drug verification. Not only electromagnetic radiation that may be absorbed by molecules, which causes them to alter. Matter may absorb energy from lasers, electrons, or tiny molecule beams, or both. This energy absorption often causes the material to lose one or more electrons, which usually results in the formation of positively charged ions.

These ions may remain whole or may endure disintegration into more permanent ions based on how much energy the source provides. The resulting collection of ions is known as the mass spectrum, and the processes employed to produce it are jointly referred to as mass spectrometry. Mass spectrometers can be used for different uses. You can present samples in practically any arrangement. The device may be administered with solids, liquids, and even gases. A mass spectrometer may be made to function as a sensor for a liquid or gas chromatograph.

The only method that can reliably demonstrate that a drug is present in the body is mass spectrometry.(*Fundamentals of Forensic Science - Max M. Houck, Jay A. Siegel - Google Books*.)

3.3. Forensic Accounting

For any country to prosper, it is important to have a robust and well-regulated economy free from frauds and scams. Due to various economic shock and banking failings, the investors have lost their trust and faith in the existing banking system. Various frauds have been attributed to the closure of banks and have completely devastated the investors and the financial establishments. According to an annual report submitted by the reserve bank of India, in the year 2021-22 banks and other financial institutions have suffered frauds to the tune of 60,414 crores.

The report suggests the commission of 23.69% higher frauds at 9,103 in 2021-22 as against 7,359 frauds in 2020-21. The private sector entities have reported maximum frauds related to small value cards and internet frauds. Whereas on the other hand the public sector banks have added maximum to the fraud amounts mainly in loan portfolios.(*RBI Annual Report: FY22 Saw More Bank Frauds but Value Decreased by Half | Banking News - Business Standard*.)

There has been an abrupt increase in different types of economic crimes throughout the world. These crimes include fraud in banking and corporate sectors, manipulation in stock markets, counterfeiting of currency, bribery, and embezzlements. A global survey carried out by Association of certified frauds Examiner (ACFE) had published its findings ‘The Report to the Nation’ in the year

2020. The report has revealed that in 125 countries nearly 2.504 cases of frauds had resulted into loss of US$3.6 bn. (Association of Certified Fraud Examiners (ACFE) (2020),)

As evident, economic crimes are incessantly growing with the constant use and dependency on technologies. This has exposed the investors to various financial offences such as money laundering, accounting frauds, corruption, asset misappropriation and anti-trust violations. The economic crimes don't simply imperil the country's economic health but also maligns the reputation and brand of a company, dropping of shares in the market and continuous involvement in litigations.(McLeod & Duthie, 2012)

3.3.1. Understanding Forensic Accounting

The study of forensic accounting is exponentially expanding in the field of financial audits. Forensic accountants act as a catalyst of accounting profession and are considered as rising stars as they are sought by more and more companies and corporations to save them from frauds and scams. Till now it was believed by the public including directors and officials of different managements and companies that exposing frauds was integrated with financial auditing and accounting study. The financial auditors were expected to protect against the frauds through timely audits of the accounts.(Dhar & Sarkar, 2010)

Now people have clearly understood the demarcation between the function of the financial auditors and forensic accountants. The task of the financial auditor is to simply check the company's accounts, accounting reports and to ensure compliance with the standards of accounting principles and policies. People have recognized that there exists a need for different accountants who are expert in investigating fraudulent transactions occurring in various financial institutions, companies, and corporations.(Dhar & Sarkar, 2010)

Forensic accounting had evolved in the beginning of the 1900's to shelter the expansion of businesses in North America. Despite this there was as such no

separate practice of accounting that dealt with frauds and forensic issues. Forensic Accounting today is entirely different from what it existed earlier and is still undergoing changes.(The Past, Present, and Future of Forensic Accounting - ProQuest.)

3.3.2. Definition of Forensic Accounting

To date as such there is no largely accepted definition of forensic accounting. The reason for the divergence of opinion is primarily the practice, background, and the experience of the forensic accountant. As a result, there are different definitions propounded by various authors and institutions. Forensic Accounting involves the implementation of investigative skills and specialized knowledge owned by the certified public accountants (CPAs) to accumulate, examine and assess the evidential matter and also to elucidate and convey the results in the courts, boardroom or any other legal authorities.(Institute of Certified Public Accountants Minority Business Development Committee.)

The term forensic accountant has been defined by the American Board of Forensic Accountant as an expert conducting inquiry, examination, analysis, test, investigation to infer the truth and formulate an expert opinion.(Ebaid, 2022)

The term Forensic Accountant has been decoded by the Association of the Certified Fraud Examiner as a professional having both accounting and investigative skills generally required for inquiring financial offences or assisting the court as an expert witness.(Association of Certified Fraud Examiners (ACFE) (2020),... - Google Scholar)

Forensic Accountants are acquainted with sound understanding of financial statements, the capability to thoroughly assess them, having knowledge of frauds and scams along with the ability to control and examine the risks.(Practical Research Corporate Governance.)

3.3.3. Expertise Required for Forensic Accounting.

In the practice of forensic accounting the forensic accountant is expected to hold expertise which is far broader than the one possessed by the financial accountant. A forensic accountant must be an expert in investigative skills and should be able to bust out various designs of frauds. Forensic accountants must be innovative in discovering various methods opted by the spurious for the commission and concealment of fraudulent transactions.

They should have sound written and communication skills as they are required to precisely present the reports and results before the courts and other financial or administrative agencies. (Harris, C. K., & Brown, A. M. (2000). The Qualities... - Google Scholar.)

Forensic accountant should be smart enough to divulge important facts from people not cooperating during interviews.(Messmer, M. (2004). Professional and ethical values along with technical, analytical, and accounting skills are important for forensic accountant.(Salleh & Aziz, 2014)

The results submitted by the forensic accountant after proper examination, inquiry and analysis of fraudulent transactions and scams should be lucid and supported with facts and proofs. Various financial institutions, insurance companies, banks and government departments like police, vigilance commission hire forensic accountants for investigation and inquiry. After the search, presentation in the form of reports along with important evidence and documents is made by the forensic accountants.(Dhar & Sarkar, 2010)

Forensic accountants also aid in criminal trials by appearing as expert witnesses in courts. Therefore, it's important that forensic accountants are familiar with legal studies including the procedures followed during investigations and trials. Forensic Accountants are engaged to quantify the economic damage occurred in cases of personal inquiry or losses suffered due to vehicular accidents or medical negligence. Forensic accountants are also engaged to compute claims under various

insurance policies either by the insured or the insurance company.(Dhar & Sarkar, 2010)

3.3.4. Exigency of Forensic Accounting Education

Due to the non-performance of audit work and failure of the organization to perform efficiently there has been an abrupt rise in the use and application of forensic accounting. Forensic Accounting has been listed as the top 20 hot jobs in future.(Forensic Accounting Is Hot Job - ABC News.) The Global Economic Crime Survey, 2003 had revealed the requirement of the use of forensic accounting in fraud detection.(Global Economic Crime Survey •, 2009)

The study of forensic accounting amongst students develops important analytical, technical, and documentation skills that help them to become successful auditors, tax professionals, forensic accountants. Imparting fraud education to graduating students equips them to effectively combat frauds and fraudulent transactions. Generally, universities offering financial auditing and accounting courses do not provide forensic accounting education.

Including forensic accounting course in financial curriculum enables the students to enhance their knowledge, experience, and judgements pertaining to frauds. Forensic accounting helps them to assess the risks related to frauds, analyze the loss, and review the risk capabilities.(Carpenter et al., 2011) Hence it is extremely imperative to incorporate Forensic accounting courses in financial accounting curriculum by educational institution offering the course.(Luke, 2013)

With slight modification in the existing financial accounting curriculum, the concepts and topics of forensic accounting can be easily taught to the students, building their skills required to be a successful professional.(Corkern et al., 2013) Integration of forensic accounting with financial accounting curriculum can be another effective way of introducing the subject in educational institutions.(Prita et al., 2014) The role of forensic accountant includes the investigation of fraudulent transaction. Also, they appear before the court as expert witnesses. It is therefore

important for forensic accountants to be familiar with laws and statutes related to fraud and corruption. Imparting forensic education to the students of law as a separate course will provide necessary skills to recognize corruption practices and frauds.

3.4. Forensic Entomology

3.4.1. Introduction

Forensic entomology is an important branch of forensic science in which information about insects is utilized to draw inferences in criminal investigations in instances involving both humans and wildlife. Both on land and in water, insects can be utilized to probe a scene of crime.(Anderson, 1995) Insects are crucial to the decomposition of bodies and can offer crucial hints in criminal inquiry and examinations. When the post-mortem interval (PMI) is extensive and other procedures are ineffective, entomological findings is very helpful in determining the timing of the death.(Catts & Goff, 1992) Additionally, insects supply forensic evidence with geographical or temporal information that is otherwise impossible to get. Forensic entomology relates to death investigations.

Numerous forms of forensic investigations can benefit from information of the location, anatomy, and conduct of insects present in areas where carcasses have been located as it can indicate investigators when, at what place, and how a crime was perpetrated or how a person died under specific circumstances.(Morton & Lord, 2001) Insects like rove beetles, nematodes, cheese skippers, hide and seek beetles, isopods, opiliones, blowflies, flesh flies, can help in forensic entomological examinations. Few species, at their larval stages feed on carrion and eat dead corpses. In some, both the adult and juvenile phases consume the organism. Other insect groups, however, are drawn to the body only to feast on the necrophagous larvae that are already there. Arthropods samples like Diptera, Coleoptera whether maggots or adults should be regarded as forensic proof in the same way as biological materials like hair fibers, fingerprints and blood stains.(Lord & Burger, 1983a)

Both at the postmortem and the scene of the crime inspection, insects should be treated as evidence.(Haskell et al.) To maintain the chain of custody, avoid pollution, and check the tampering of evidence, forensic entomology must also employ a structured, reliability strategy while collecting, preserving, and even labelling and transporting entomological samples. This is also important because entomology involves dealing with living things that need to be handled carefully. There are three different identified categories of forensic entomology.

1. Urban forensic entomology
2. Stored-product forensic science.
3. Medicolegal forensic science

Urban forensic entomology covers topics like court cases and civil lawsuits concerning pest arthropods in homes or gardens. This includes legal actions involving pesticide abuse. Infestation or pollution by arthropods of a variety of commercial items such as beetles or their portions in chocolate bars, maggots in sauce, or spiders in toilet paper is the focus of stored-product forensic entomology. Lawsuit typically falls under this category, just as its urban equivalent. (Smith K. G.V. (1986). A manual of Forensic Entomology. London: British Museum (Natural History), Comstock. 205.) Medicolegal forensic entomology is the third category, which is also termed as Medico criminal entomology.(Entomology and Death: A Procedural Guide) It focuses on the role of arthropods in incidents involving offenses, most frequently violent ones like homicide, suicide, and sexual assault, however it also covers other felonies including physical violence and drug trafficking.

The medico criminal category is most frequently used in mortality examinations. The period of death, the time of body disclosure, the time between death and body finding known as the postmortem interval, (PMI), transportation of the body, method and reason for death, and linkage of perpetrators with the death site are all related to arthropod occurrence and activity and are the pertinent areas of investigation in criminal medical category.

3.4.2. History and Development of Forensic Entomology

Long-standing evidence of the use of insects in solving crimes has been documented, and several scholars have published on the development of forensic entomology.(Benecke, 2001) As early as the middle of the eleventh century, the Chinese employed the inclusion of flies and other bugs as one of their diagnostic equipment when examining crime scenes. (CHENG KO. Cases in the history of Chinese Trails 34 Greenberg B. and Kunich J.C. eds. Cambridge University Press 2002 1890)

A teaching handbook on detecting homicide was produced in 1235, because of the significance of insects in crime scene analysis. It is noted in this medico-legal literature that an accused was forced to admit to the killing of a fellow Chinese farm worker with a certain sickle after many blowflies landed on it. Numerous biological advancements made between the fourteenth and the nineteenth centuries set the groundwork for forensic entomology to evolve into a field of research. The two most significant contributions were possibly Redi's (1668) studies in Italy, where he used the meat of several species of animals to show that fly larvae evolved from their eggs. Also considering the effort that Linnaeus (1775) made to create a categorization system of insects.

In doing so, Linnaeus offered a method of detecting insects, which included recognizing forensically significant flies like Calliphora Vomitoria. These advancements laid the groundwork for the calculation of the duration of the stages of the life cycle of an insect and the creation of techniques indicating the time of death. The killing of an infant was an especially noteworthy court trial that contributed to the acceptance of forensic entomology as a legitimate technique for criminal case investigation.(Infanticide, Momification Naturelle Du Cadavre 4... - Google Scholar.)

When boarding house renovations were being done in 1850, the decomposed body of the infant, which had been sealed within a chimney, was discovered behind a mantle. After performing a postmortem on the deceased, Dr. Marcel Bergeret found

several moths and maggots of the flesh fly Sarcophaga Carnaria. He came to the decision that infant's bone was locked inside the room during 1848, after a span of one year i.e., 1849 the moths had gotten inside it. Due to this calculation of the post-mortem period, occupants of the residence before 1848 were charged, while the current occupants were acquitted.(Infanticide, Momification Naturelle Du Cadavre 4... - Google.)

Mégnin's findings and deductions led to the next important development (1894). He compared the progression of insects populating the corpse after dying to the eight phases of biological degradation. Later research showed that the speed of such phases of decay varied and depended on ecological conditions, such as weather and, for instance, if or not the body was dressed. However, it has been shown that the general breakdown process and the importance of the insect relationship are identical for a variety of creature species. The understanding of insect progression on a carcass served as the foundation for forensic entomologist's calculations of the corpse's timing of demise.

In court cases concerning insect occupancy of parts of the body retrieved from water and full bodies discovered on land in the 20th century, arthropods were demonstrated to be valuable. On September 29, 1935, numerous corpse pieces that were subsequently determined to be those of two ladies were found in a Scottish river close to Edinburgh. The victims were identified as Mrs. Ruxton and Mary Rogerson, who served as nanny.

The blowfly maggots, which were developing in their third phase, demonstrated that the babies had been placed before the bodies had been submerged inside water. As a result of such disclosure and further proof, Dr. Ruxton's husband was found guilty of killing his wife along with Mary Rogerson.(Hammond, 1952) Like Megnin, numerous researchers have made significant contributions to promote and justify the use of entomology in death inquiry as seen by law execution and investigation organizations.

Forensic entomology was accepted as a legitimate scientific and medical field of study in the late 20th and early 21st centuries. Academicians and medical experts have collaborated with law enforcement and other government agencies for the acceptance and development of forensic entomology.

3.4.3. Relevance of Insects in Criminal Investigation.

Use of insects in mortality examinations is justified for several factors. Typically, insects are the quickest to discover a dead body. The blow flies frequently lay their eggs on carcasses during the first few moments after a death. (Catts, E. P. Problems in Estimating the PMI 9) This event begins a biological clock, and the age of the growing fly offspring is later determined as the foundation for calculating the PMI. As the decaying process advances, the invertebrate fauna inside and around a body transforms in a reasonably regular successional manner. A diverse variety of creatures, from bacteria to vertebrate decomposers, use the body as a transitory supply.

Insects are often the most consistent, diversified, and noticeable group of arthropods present, except for maritime environments, where Crustacea prevails. In experiments conducted in South Carolina, decomposing foetal pig corpses yielded 522 varieties of creatures in 3 classes, 84% of which were insects.(Payne, 1965) 140 arthropod species with an identical 83% percentage of insects were reported in similar investigations conducted in the Hawaiian Islands.(M. L. Goff et al., 1986)

When detectives examine the death site, the carcass fauna is usually disregarded. Arthropods found close to the deceased body are frequently dismissed as proof. For instance, if samples are only taken from the dead body at the death scene or during the postmortem, a whole ecosystem of maggots and insects that are formed beneath the carcass may be lost as proof.(Acarol 1989.) Different ecological functions are performed by the various species of arthropods. Their roles may be classified into the following different categories.

3.4.3.1. Necrophages

They are the type of organism that eats carcass tissue. This category consists of Coleoptera e.g., Silphids and Dermestids and Diptera, particularly Calliphorids, Sarcophagids. Usually, determining the age of these insects serves as the foundation for developing PMI estimates. (Marchenko, M. I. Flies Biology: The Forensic Medical Role)

3.4.3.2. Generalist Feeders

Species that consume both the body and the surrounding fauna are known as Omnivores. This includes ants, bees, and certain beetles. Massive numbers of these species might slow the rate of body decomposition by reducing necrophagous species populations.(Early & Goff, 1986)

3.4.3.3. Predators

This category of arthropods was ranked second in significance to necrophages. (Smith, K. G. V. A Manual of Forensic Entomology 1986.) Numerous Coleoptera e.g. Histerids, Staphylinids, Silphids, Diptera and those Hymenoptera that infests young flies are all included in this group.(Goodbrod & Goff, 1990) Many insects, which are necrophagous in the initial stages of their larval growth, turn predacious in the later stage. As predators of other mites, insects, and nematodes, the species like Parasitids, Uropodids, Parholaspids and Macrochelids, are likely to fall under this description.(Goodbrod & Goff, 1990)

3.4.3.4. Incidentals

Arthropods that exploit the cadaver as an expansion of their natural home and a rich supply of resources fall under this category. This class of organisms includes Centipedes, Siders, Springtails, Pill bugs, and several mites including Lardoglyphidae and Acaridae.(Goodbrod & Goff, 1990)

Insects from any of these groups may offer valuable evidence for the inquiry to the forensic entomologist. The American entomologist J. A. Payne provided ample evidence of the significant role that arthropods, particularly necrophagous species,

play in the breakdown of carcasses.(Goodbrod & Goff, 1990) He, throughout the summer, observed the decomposition of piglet carcasses in woods.

The piglets in one of the groups were covered with netting to keep insects out, whereas the other group of carcasses was left exposed and readily available to insects. In contrary to the covered corpses, which progressively shriveled out over the course of more than 100 days, the unprotected piglet carcasses lost 90% of their weight during the first week. Scrounging insects are initially drawn to bodily secretions such as urine, faeces and saliva flowing from natural apertures and to any blood leaking from wounds.

The flesh eventually attracts additional foraging bug species, as do the underlying tissues and bone. A decaying corpse may be seen as a series of "nesting sites," each of which attracts and sustains a certain type of bug.

3.4.4. Variety of Arthropods on the Carcass and their Role

Insects play a significant part in the decaying mechanism by nibbling on the body mechanically and producing salivary fluids that include proteolytic enzymes to help dissolve stubborn tissues. Additionally, the initiation and acceleration of bacterial degradation is the result of these mechanical and chemical mechanisms. Diptera (fly), whose larvae can survive in a semi-liquid condition, are responsible for the primary and most severe decomposition of the body. Once the carcass has largely desiccated, members of other arthropod families, particularly Coleoptera (beetles) and Lepidoptera (moths), enter and carry on the process further.(Forensic Entomology: Insects against Crime on JSTOR.)

When flies arrive at a body, they either start ovipositing nearly immediately or initially eat before doing so. The first insects to approach generally blue bottles calliphora deposit their eggs at injuries and bodily openings, including the nose, mouth, ears, and, if accessible, the rectum and genital.(Forensic Entomology: Insects against Crime on JSTOR.) The elongate, transparent pale golden eggs may be seen with the unaided eye. According to the weather, the ovules develop into

generally shapeless, paraplegic larvae in 2–3 days. Although challenging, is recognition at this state, but is not unattainable.

Larval size is a useful characteristic for identification, even though it is increasingly significant as it gets older. The larvae develop quickly and go through three stages before reaching adulthood. At this phase they creep away from the corpse, bury themselves beneath the ground, and undergo metamorphosis. When the adults emerge, scurry to the soil's surface, and fly away, at this stage the life cycle is over.(Forensic Entomology: Insects against Crime on JSTOR.)

The blue bottles generally land on the corpse first. Every time they enter the house, their constant seeking behavior especially in dim corners is obvious. The ongoing quest for new body to deposit their eggs, explains why blue bottles first appear on carcasses. They are very essential to the forensic entomologist in determining the time of death since they are obviously drawn to meat before it exhibits any indications of deterioration.(Forensic Entomology: Insects against Crime on JSTOR.) The appropriately termed flesh flies (Sarcophaga) are additional category of flies that are drawn to the initial phases of the corpse. They either directly deposit eggs or lay tiny larvae that mature quickly. The larvae are larger than the ones in the blue bottles, but they may be readily differentiated from them through comparing the anatomy of the hind spiracle.(Forensic Entomology: Insects against Crime on JSTOR.)

Green bottles, another well-known species of flies also known as Lucilia Sericata, are drawn to the ammoniac smells of dead bodies and begin to emerge on them after approximately a week. The body is drastically altered over the first few weeks by these principal colonists, and as it dries out, it attracts various more dipterans. Fats go rotten and get creamy, creating the ideal environment for the cheese skipper Piophila casei. This fly's larvae have a wide range of appetites and are occasionally discovered permeating cheese, they also inhabit any bodies that get to this point in

the decomposition process.(Forensic Entomology: Insects against Crime on JSTOR.)

Drosophilidae and other closely connected sepsid flies are also drawn to the body at this time. After another 6 to 12 months, when the body is fully mummified and dried, the coffin flies, also known as the Phoridae, begin to occupy it. Conicera Tibialis, a phorid, may survive for many years underground by feeding on carcasses that are kept in coffins. This species may presumably access the body by tunnelling under the ground. This fly is a sign of a dead body being buried, making it a potential indicator species.(Forensic Entomology: Insects against Crime on JSTOR.)

Two more insect types, besides Diptera, are somewhat engaged in the decomposition of a body. Coleoptera, or beetles, are the biggest category of insects, making up about 25% of all species. After the first fly species have invaded the body and the residual tissues have dried out, they subsequently infiltrate. The function of beetles on corpses has not received much research. They enter in the late phases of degradation, which may be partly a revelation of how quickly humans have unearthed the bodies.

The additional insects that should be included are the ones that could have been on the body when the person died. Human ectoparasites like head lice, crab lice, and body lice are rather ubiquitous. After the demise of their carrier, body lice can survive for three to six days. As a side note, it is important to note that several parasite varieties may be found on humans. Scabies mites, if detected, are generally of little help, while Demodex, a mite that lives in hair follicles, is highly resilient and may be valuable in forensic investigations.(Forensic Entomology: Insects against Crime on JSTOR.)

3.4.5. Calculation of Postmortem Intervals

Every homicide inquiry depends on a precise calculation of the time of death known as postmortem interval. Every mysterious death inquiry needs PMI estimate to

recreate the facts and conditions of the death, connect a perpetrator to the deceased, and verify the reliability of witness testimony. It is helpful in both civil and criminal proceedings. Indeed, these assessments can have legal ramifications for insurance coverage and succession issues even if a death is natural, unintentional, or a suicide.(Greenberg & Kunich, 2002) There are several ways to calculate the PMI.

Initial postmortem alterations in sensitive body cells, resulting in rigidity, mortis, fall in body temperature, phases of breakdown, are typically used by pathologists to estimate the time since death occurred. However, since many of these techniques are rather at times untrustworthy and incorrect, the chronology of such fluctuates may only be used as a rough approximation of how long the person has been dead.(Nokes et al., 2002)

Biological degradation of human carcass is influenced by a variety of variables, some of which are directly related to the body such as condition, age, corpse integrity, and reason of demise, others are tied to natural conditions like airflow and warmth and heat circulation, moisture, garments, and availability of the body to wildlife. All these factors can be included in some mathematical equations or analytical tests that calculate PMI.(Campobasso et al., 2001)

Relying on the accessibility of instrumentation, the effect of the conditions of the death, and the climate, correct evaluation of the death historical record is not possible more than 48–80 hours after death. Some researchers state an optimum accuracy within an empirical probability level of 95% using temperature techniques or biological fluids chemistry.

In every situation, the gap prediction is less correct if the real PMI is longer. Even though within 1-3 days of postmortem, PMI can be accurately predicted by the thanatological method, after that point, entomological evidence connected to and surrounding the dead body becomes much more significant and can predict the time since death up to a time frame of many weeks or even months.(Clark et al.)

3.4.6. Procedures Opted for Estimation of Postmortem Interval

The entomological technique primarily consists of two phases used for determining the date of death:

1. The estimation is determined by the time required for each depicted species to mature that are gathered at the death site during the initial stages of decomposition. These are often blow and flesh flies and their maggots. If the body was revealed and the environment was conducive to insect activity at the start of the period, those with the longest duration of development are presumed to exhibit the PMI.(EP, 1990) Keeping in mind the main premise that insects, often flies, will find the body shortly after death or during the time of carcass exposure.(Hall, R. D., & Huntington, Medicocriminal Entomology.) When determining the PMI, this assumption must be correctly examined because there are high chances of errors. This is particularly evident in cases of confined and indoor fatalities or in places with severe weather.
2. The bodies that are in advanced decomposition stages are the focus of the second fundamental method for calculating the PMI. In these situations, PMI estimations are based on the arthropod community's makeup in relation to anticipated successional trends. (M. Goff & Flynn, 1991)

The earliest undeveloped samples obtained from the corpse are compared to the environmental parameters to determine age to which they were revealed and data on their known growth rate is collected based on Diptera benchmark growth from the exact zoogeographical region with a specified temperature. It is required to use observational evidence pertaining to the identical species with carefulness.

The gradual growth in size including weight and length over a period is a key factor in determining the larval age. But there are other factors that may be used to identify ageing larvae besides length and weight. A microscopic critical examination of the anatomy of the larval mouthparts and rear spiracles can be used to estimate the larval instar and, consequently, the estimated age. In addition, a mature third instar

larva's crop size might reveal whether it has finished feeding. It is well known that the climatic temperature to which larvae are subjected during development affects their rate of progress and growth. The most exact estimations of the heat and warmth exposed to the larvae are therefore essential.(Amendt et al., 2007)

To reproduce the temperature of the scene of death during the period in between demise and retrieval of the corpse, readings at the site are recorded for many days after the corpse was discovered. Hourly temperatures recorded by a data recorder, preferably one that has been confirmed for accuracy, can be compared to temperatures collected from the nearest meteorological stations during a similar time and examined, placed at the scene of the crime for 5–10 days. Such data can be subjected to regressive assessment to recover the actual temperature regime at the site.

Due to potentially significant temperature changes between the interior and exterior of buildings, this can be particularly crucial. Because variations in interior temperatures frequently delay variations in exterior heat by 1-3 hours or more because of the building's insulating qualities, temporal adjustment may be needed to enhance the regression. If the warmth is quite consistent, as it is in the case of certain corpses recovered within, the size of the maggot can be used to estimate the age of the organism.

Between the points of the reported transformation, such as incubation, prepupal development and emergence from pupa, an age range may be established, at the highest and minimum temperatures is mostly changeable, generally in the case of corpses discovered outside. However, if the size reduction prior to pupariation or the probable shrinking impact of some lethal and preservation treatments are not taken into consideration, a PMI calculation based only on larval size might be deceptive.(Tantawi & Greenberg, 1993)

3.4.7. Successional Sequences in Arthropods

Scientists may connect each variety or group to a recognized stage of decomposition through the study of arthropod succession. Observation of the microbiota on a corpse can be utilized to provide a reasonable estimate of the postmortem interval i.e., decomposition provided that the chronology of arthropod colonizing carcass in a specific place is known.

There are forensically relevant schedules displaying the proportionate diversity of various bug species at different times, although this needs a lot more study. The PMI estimated using this approach is, however, still highly imprecise; this is despite the researchers' best attempts to fully understand all the aspects determining the makeup of the carcass's arthropod population.(Varatharajan & Sen, 2000)

3.4.8. Collection and Examination of Samples at the Site of the Crime

The best method to react to a request to visit a scene of crime is to be prepared with a toolbox that has everything needed to gather entomological specimens. As a result, there isn't a significant delay in responding to requests, and most eventualities may be handled. If the entomologist is requested to visit the crime site, he must gather enough samples so that they may be made accessible, if required and desired, by other experts to do their own analysis for the defense.

It is crucial because the family may want to see the body before it is disposed of, they need the body to be free of insects therefore it is imperative to carry out cleanliness control exercises, which means that the environment in question will change; in this case, efficiency and effective sampling strategies are required.

3.4.9. Entomological Tools and Preservatives Required to Collect Samples from a Carcass

The necessary entomological supplies entail jars of plastic with open top for collection of live cultures, surgical instruments, stepping slabs to prevent pollution. There are a number of stabilizers that may be used, each with benefits, including alcohol.(Adams & Hall, 2003)

It is vital to provide food for the living specimens since they must be removed from the place alive. The best options have been determined to be minced beef or pig's liver. However, it should be mentioned that studies suggest larvae exhibit varying development on various body parts. The meal should preferably not be chilled if fed to the larvae rather, it should be at room temperature.(Adams & Hall, 2003)

There should be a carrying box or wrapping used for specimens. Specimen jars containing both preserved and living specimens should be kept together in pairs. To ensure the authenticity of the sampling is not compromised when samples are obtained by a crime scene investigator rather than a forensic entomologist, the samples must be packaged and sealed. The packaging must have holes drilled into it, and the culture jar lids must also have small pores that securely fastens the vessel. It is important to document the general environment at the scene of a crime.

The characteristics of any vegetative cover, the incline of the ground at the murder site or, if the body was discovered outside, the location and an overall location summary, alongside related pictures, should be documented. If the body was found inside, whether it had been enclosed or encased in some way; whether the windows were open or sealed. Along with the intensity of light or shading at the site, it is also necessary to note the temperature at the scene of a crime. The entomologist equipment case should also have thermometers. These thermometers must be calibrated to provide high accuracy readings without the need for further correction.(Adams & Hall, 2003)

3.4.10. Entomological Approach for Egg and Pupae Sampling

The corpse should be examined in an efficient manner after obtaining consent from the chief investigating officer. Before continuing with the limbs, the head area is to be initially inspected, followed by the torso. Any injuries are recorded carefully. When the body is removed of its garments, especially in mortuary a more comprehensive search is conducted. Eggs of flyers are placed in aggregates and can be confused for anything from sand to a salt encrustation on the corpse to

yellowish-white mould. Beetles generally lay single egg and possibly are overlooked at the scene of crime.

Therefore, it is crucial to inspect the body from all angles, and if the body is fully dressed or has been encased in anything, it could be essential to witness the autopsy to screen for insects further. Picking out the single egg clumps and meticulously putting them in a jar with no food is required. To prevent the eggs from drying out, it is important to maintain the dampness in the container by placing a moist paper napkin inside the tube. Each sample must have a unique item number and information about the crime scene. Permanent ink ought to be used to write the label. The identity of the examiner at the scene of crime taking the specimen, the official taking the charge of such investigation, proper numbering of the cases, the number of the specimen, the day, date, and which part of the corpse the snippet was obtained is to be listed on the label. By including these details inside and outer part of the container, it is less likely that the information will be lost and mixed with unknown origin. Additionally, these details must be provided in scene record.(Lord & Burger, 1983)

Typically, fly puparia are located some range away from the host. The post feeding phase of larvae moves so they may be in pockets, in plant debris, or in any crevices that are present in structures. They can also be found 3-5 cm below the topsoil. If the puparia are still present on the corpse, either a specific kind of bug is suggested or there may have been some restrictions on larval movement. All puparia, regardless of colour, should be collected since puparia transform from white to dark brown over time.

To achieve this, a well-planned exploration approach should be employed. If the corpse is not inside a house, it is optimal to search a 36 square metre area in a grid of one metre intervals. The topsoil should be scraped with a shovel to a depth of 10 cm at the grid intercepts for this laborious, time-consuming task. As stated before, the puparia that are collected are put inside a jar along with wet tissue roll and

appropriately branded. If at all feasible, the puparia should be cultivated up to emergence so that the species may be positively identified. The puparial case should be kept around as added proof. Pupae that do not develop serve as instances of scene samples that have been conserved.(Gennard, 2012)

3.4.11. Capturing Flying Arthropods at the Site of the Crime

Before manually gathering any samples from the cadaver, flyers at the site should be caught using a net. This is because they are most readily caught with a net and could vanish if disturbed. The bug is caught inside the net after it is flipped from behind in an upward stroke. After that, the mesh should be pressed down on itself. with a wrist swing to trap the bug. Now that the insect is constrained in the net base, it may be covered by a container by grabbing the net with the other hand.

A good shake generally maintains the bug in the tube's bottom long enough for the lid to be placed on top. These flying insects can either be stored collectively from the murder scene or stored in separate killing jars until they are all dead. They are then put into separate specimen jars. Since insects can move everywhere, they serve as a good representation of the entire crime scene. In every situation, precise labelling and documenting are essential.(Gennard, 2012)

3.4.12. Relevance of Forensic Entomology in Court

This result of all the gathering, detecting, and computing done as a forensic entomologist is the creation of a document for the person or organization giving you the instructions; in certain cases, this report may be for someone who is seeking legal action. You might not need to appear in court if this report is sufficiently thorough and the results are conveyed properly. To effectively convey the findings of an investigation, it is important to develop clear and succinct communication skills. It is also important to make sure that all investigation notes are well recorded and are accessible to the court upon request.

Finally, it is important to accurately compile, summarize, and retain data from the crime location, including written documents and protected crime scene. Finally, it

is important to accurately compile, summarize, and keep records of details from the crime site, such as documentation along with safe crime site samples that were later retained as the insect life cycle progressed.(The Utility Of Arthropods In Legal Investigations.)

There are numerous reasons why a forensic entomology report can be required. A report may be submitted in response to an entomological problem that may later be raised in court proceedings in a criminal or civil court. Entomology reports are helpful for the evaluation and ascertainment of veracity and importance of evidence.

Reports may be extremely beneficial for lawyers and attorneys in murder cases. Entomology reports also help in establishing the authenticity of the structured declaration of testimony that is offered to the judicial bodies for consideration in hearing in trial. A rational explanatory scheme and information clarity are required in every such cases.(Adair, 1999)

3.4.13. Study and Application of Forensic Entomology in India

Regrettably, there aren't many forensic entomology labs in our country for conducting experiments necessary in this domain. Contrary to other nations where ongoing systematic, scientific, and biological investigations are carried out to reach relevant findings, in India reports of records are more frequently from the perspective of classical taxonomy. Many factors that affect decomposition are frequently ignored.

The results of a successful inquiry depend on these interconnected aspects, such as insect movement, weather conditions, precipitation, burial depth, predator presence, etc. Only until forensic entomology is included in the educational course of Indian universities under Applied Zoology/Entomology will there be more interest and progress in this discipline.(Keh, 1985)

3.4.14. Concluding Remarks

There is no doubt that insects have a lot to offer in forensic science. Their value can only be realized to the full extent if the investigating officer, technicians, the police, pathologists, technicians, and others involved in crime-solving are clearly cognizant of the intricate ecology of the decay process, the requirements of the decomposer organisms, and the importance of gathering crucial samples and helpful field data. The use of pesticides in autopsy rooms has resulted in the loss of important entomological data or has negatively impacted such data.

Every forensic science laboratory should have the resources and knowledge necessary to establish developmental times, which are crucial for determining the time of death. A sleepy backwater, forensic entomology is now being acknowledged as a potent forensic tool.(V. R.-T. C. Journal 2005.)

3.5. Cyber Forensic

3.5.1. Introduction

By misusing information and utilizing the channel for the goal of doing evil and committing crime, humans are doing more damage to society. Data security and information restriction become major concerns when we discuss the privacy of data. Because of the exponential rise of cybercrimes and the constant introduction of novel technologies, it has become very challenging to find an immediate resolution to every cybercrime. It is very difficult to guarantee that data on the web or on our system is entirely protected.(Sharma & Kaur.) It is predicted that the world will have 21 billion IOT (Internet of Things) gadgets by 2020, and these devices will interact with one another. Even your watch, pen, and shoes, will be linked to the web and have IP addresses at that time.(Li & Xu, 2017) The convenience of quick and simple internet accessibility has increased with technological improvement. However, in addition, cyber criminality has grown rapidly and now poses a risk to societal structure that must be addressed.

Laws such as the Information Technology Amendment Act of 2008, The Indian Evidence Act (now The Bharatiya Sakshya Adhiniyan 2023 and the Indian Penal

Code 1860 (now The Bharatiya Nyaya Sanhita, 2023, have formalized regulations that sanction any criminal engaged in cybercrime, yet the ongoing development of software and the crafty yet bright minds of the perpetrators occasionally pave a way out. Every action a person does online leaves back digital traces that can be used to identify them, their past behavior, and the timings of such action taken. Cyber forensics is indeed more important now than ever to ensure our safety as we spend an increasing amount of our time online because as technology advances, so do criminal activity.

To examine and extract digital information from software systems, communications networks, wireless connectivity, and storage drives in a fashion that is admissible in a courtroom, the discipline of cyber forensics incorporates principles of computer science and law.

3.5.2. Delineating Cyber Forensics

Cyber forensic is the science of detecting, gathering, safeguarding, evaluating, and presenting digital evidence from technological devices like laptops, hard drives, cell phones, etc. that are employed to perpetrate a crime.(Prasad et al.) A digital device that has been employed to perform a cybercrime may hold information that a cyber forensic specialist can find in a variety of ways. Using the right equipment and procedures, they can extract information from encoded, erased, and corrupted files. The retrieved information is then used to solve the offence and is crucial to the legal process. The forensic professionals conduct a comprehensive examination of the computer system showing every obvious trend following the detection of concealed files and the restoration of erased files.(Prasad et al., p. 388)

The extensive fields of digital forensics and computer forensics are used to look into offenses like phishing, financial fraud, and mail spamming, among others. The science that unifies all the examinations and analysis required to solve these kinds of cybercrimes is known as digital forensics(Richard & Roussev, 2006) The practice of gathering, retaining, analyzing, and disseminating digital information

with the help of a computer network as a tool for the commission of a crime is known as computer forensics.(Patzakis, J. (2003). Computer Forensics as an Integral.)

Cyber forensic focuses on looking for gadgets that can store digital information. Digital forensics is a field of forensic sciences that seeks to confront the lack of concrete proof of crimes. Therefore, an inquiry into unusual or dubious activity in cyberspace or online world is known as a digital forensic investigation.

3.5.3. Historical Overview of Cyber Forensics

What is currently referred to as cyber forensics was diversely described as "computer forensics" till the late 1990s. Law enforcement professionals with a knowledge and passion for computers were the pioneer digital forensics specialists. In the USA, the FBI Computer Analysis and Response Team (CART) started operations in 1984. The UK's Metropolitan Police established a cybercrimes division, a year later under John Austen which was referred as the Fraud Squad. At the start of the 1990s, a significant change occurred.

The UK law intelligence departments' analysts and support staff, as well as external experts, acknowledged that cyber forensics needed established methodologies, standards, and processes just like other disciplines did. These frameworks did not already exist but were required to be created immediately. The present British cyber forensic approach was developed throughout a sequence of seminars that were initially organized by the Serious Fraud Office and the Inland Revenue at the Police Staff College in Bram shill in 1994 and 1995.(Carroll et al.)

Cyber forensics as a field of study first emerged in the late 1990s and early 2000s. Everyone with a stake in the judicial framework, criminal justice system, decision-makers, corporate leaders, educators, and the government is intrigued in cyber forensics. Both the practice of criminal procedure and private inquiry frequently use cyber forensics. For something to withstand cross examination in courtroom, it needs to meet strict criteria. Human testimonies are crucial because court system

won't accept software applications like Encase, Pasco, and Ethereal as specialist witnesses, hence cyber forensic is turning into a reliable source of examination.(Kent et al.)

Many professions, including the army, commercial enterprise, academics, and legal jurisprudence, can benefit from the application of cyber forensics. Information security, data collecting, visualization, excavation, probing, standardization, evaluation, and dissemination are just a few of the many requirements in these fields.(Saurabh et al.)

3.5.4. Relevance and Application of Cyber Forensics

The purpose of Cyber forensics is to locate digital information so that an examination can be conducted using the empirical approach to reach findings. Juvenile obscenity, illegal technology use, and online harassment are a few examples of cases that make utilization of digital forensics. The discipline of digital forensics has become a popular research area for the following reasons:(Turnbull et al.)

a) Cyber Forensics enable the administrator to identify problems,
b) To prevent cybercrimes, remote monitoring systems are essential.
c) Preemptive forensics can be used to track cybercrimes.

Cybercrime is not yet definitively defined, but in the foreseeable future, some specialists have offered an understanding of what it is. In 1995, Sussman and Heuston initially suggested the phrase "cybercrime." Cybercrime is best understood as a group of operations or practices; and as such there is no single term that adequately defines it. These actions are dependent on the tangible offence item that has an impact on computer systems or data. Congruently cybercrime can be defined as use of computers and the Internet for nefarious purposes.(Brinson et al.) Cybercrime is often referred to as digital crime, e-crime, high tech crime, information age crime, etc. The proportion of cybercrimes trends is growing because of internet expansion since it is no longer necessary for the perpetrator to

be physically involved to conduct a crime. The peculiar aspect of computer crimes is that it's possible for the target and the perpetrator to never have a face-to-face encounter. To decrease the likelihood of being discovered and punished, cybercriminals frequently choose to function from nations with absent or lax cybercrime legislation.

As per David Wall cybercrimes are classified into three different forms (Gupta, A. K.., & Gupta, M.K. (2012). E-Governance.)

a. Crime committed against machines e.g., phishing, malware attacks by planting a virus or other harmful programs on computers or other equipment with web connection, to damage the operational system.
b. Crime committed using machines like financial frauds.
c. Crime in the machines e.g., child obscenity, spreading communal violence through provocative speech and offenses in social networks.

3.5.5. Different Stages of Digital Forensic Investigation Processes

According to the National Institute of Standards and Technology, the full inquiry procedure for digital forensics is categorized into following categories(QC et al.)

3.5.5.1. *Gathering Stage:*

The identification of possible data resources and the acquisition of forensic evidence from them constitute the first phase in the forensic examination. Computers, storage devices, modems, smartphones, digital cameras, and other devices are significant data providers. A strategy is created to gather data based on factors such as relevance, variability, and effort required.(Crime, 2015.)

3.5.5.2. *Assessment Stage:*

After data has been gathered, the following step is to analyze it, which entails evaluating and obtaining the pertinent details from the data.

3.5.5.3. *Testing Stage:*

To draw inferences, pertinent retrieved data are analyzed. In-depth data gathering will be required if more information is required for a detailed examination.

3.5.5.4. *Reporting Stage:*

This is the practice of putting together and disseminating the findings from the analysis phase.

3.5.6. Cybercrime Participants

3.5.6.1. Victims of Cybercrime

Becoming a part of the online community that builds up the commission of cybercrime is a concealed risk if the basic safety precautions are not accessible, as every consumer in cyberspace could become the subject of a criminal attack. It should be noted that just being a user only qualifies one as a prospective victim and that too when harm has actually been done.

3.5.6.2. Cyber Criminals

People falling under this heading use information and communication technology to commit a crime. Although we may assume that they are experts with an understanding of technology or telecommunications, this is not necessarily the case. The Internet tends to democratize availability of data, but it has also a propensity to democratize some illegal behavior. For example, fraud is made easier for non-computer professionals to commit online.(Bauer et al.) Additionally, the deterritorialization made possible by the Internet encourages professional criminals to commit crimes in more intricate methods that are harder to detect and prove. One such example is organized crime. E-delinquents are operating together since they are virtually dispersed around the world wide web and are not physically confined to one location.(Forensic Application of DNA 'Fingerprints'. Nature.)

3.5.6.3. State Agencies

Government agencies with expertise in cybercrime make up the third segment of this framework. These organizations are responsible for:

a. protecting web consumers in their task to avert crime.
b. repairing harm done to cyber victims; and
c. pursuing computer hackers for indictment and sanctions.

The advantages of the Internet, such as the frequently computer-controlled communication, screen-to-person commerce, and worldwide system integration, can be a dual-edged sword in terms of cyber privacy, making it more difficult for state organizations to prosecute offenders. Furthermore, the capability of cyber offenders can surpass the level of expertise and understanding of the cyber experts in agencies, making avoidance and e-safety training for Online consumers the best defense against victimization.

Cybercriminals may find heaven in certain online tools that disguise the credential of a user. In complement to the unsecured web that we are familiar with, there is a concept known as the "Dark Network" or "Dark Web" where users can remain unknown by not disclosing their IP address and maintaining the confidentiality of their interactions. With this kind of system, data, key locations, and routing algorithms enable operator secrecy. The program known as Tor, whose name is derived from the term the onion router, which means "Onion Routing," is one of the most well-known programs on the dark web.

In accordance with the system's interface, everybody can utilize this application, including families, businesses, activists, scholars, the press, and the military. It must be downloaded on a device before it can be used to retrieve the confidential data that is stored there. Although the ability to communicate in nations where the web and the data that percolates are heavily regulated, particularly in situations where the nation is viewed as repressive, it is generally laudable to use of such application, but also the despair it provides creates an environment where it is possible to participate in illegal activity like child pornography or correspondence for terrorist reasons.

3.5.7. Variant Nature of Cyber Crimes and National Standards for its Prevention

With time, there has been a rapid rise in cybercrimes. The development of new technology has made criminals' minds keen and devious, and many offenses are now being perpetrated on the internet. Despite the fact that technology advances more quickly than the legislation, the latter still discovers the solution to uncover such offenses and further prohibit them.

3.5.7.1. Unlawful Access: Hacking

Typically, it alludes to an unlawful entry into a computer system or network. A hacker is a talented coder who engages in hacking. The goal of hacking is to change computer systems. To engage in unlawful acts including compromising commercial or confidential data, identity theft, privacy violations, etc., the hacker may modify the software or alter the security protocols. The Information Technology Act (I T Act) of 2000 contained provisions referring to "hacking". After the revision, in the year 2008 the provisions (Information Technology Amendment Act, 2008 Act 10 of 2009.) that covered hacking were eliminated in order to protect the interests of conscientious and lawful hacking carried out bonafide by professionals.

It made a contrast between criminal hacking also referred to as "cracking" in layman's terms and moral hacking. The IT Act of 2000 does not specifically include the term "hacking," but it does include provisions for malevolent and unlawful cracking/hacking under sections 43 and 66 of the statute. The IT Act, 2000 specifically under sections 43 and 66 applies to this particular infraction.

As per section 43, If an individual accesses or secures access to a computer, computer system, or computer network without authorization from the owner or the person in charge, or downloads, copies, or extracts any data, computer database, or information from it, they are in violation of the law. Furthermore, section 66 of the Act serves as an addition to *section 43* by asserting that any individual who engages

in any conduct described in section 43 deceitfully or unlawfully shall be imprisoned for a period that may stretch to three years or with fine that might also be enhanced to rupees five lakh or with both. (Information Technology Act, 2000 s. 66)

The Indian Penal Code 1860 specifically under section 378 read with section 379 defines crime and stipulates punishment for the same (The Indian Penal Code 1860, s. 405) (now sections 303, 305 The Bharatiya Nyaya Sanhita, 2023) also section 405, explains Criminal Breach of Trust and 406 prescribes the punishment for the same (now section 316 of The Bharatiya Nyaya Sanhita 2023 (BNS). The above-mentioned sections apply to the crime of unlawful hacking/cracking.

3.5.7.2. Impersonation

It means pretending to be someone else in order to obtain sensitive information about the user, like banking and credit card credentials, etc. While committing a crime, such as drug smuggling, financial fraud, trafficking, or other cyberattack, identity fraudsters have the ability to employ someone else's identity. Section 66 C of the Information Technology Act of 2000, states that anyone caught using another user's digital signature, passcode, or other personal identification attribute, deceitfully faces up to three years in prison as well as other penalties including fine up to one lakh rupees. (Information Technology Act of 2000 s. 66C) In addition, offences under the Indian Penal Code 1860 such as theft (Indian Penal Code 1860, s. 378) criminal breach of trust (The Indian Penal Code 1860, s. 405) and cheating and dishonestly inducing handover of property (Indian Penal Code 1860, s. 415, 420) are also applicable to the offence of identity theft (now sections 315, 318).

3.5.7.3. Child Exploitation & Soliciting

Online child sexual abuse and child solicitation occur when minors are approached for pornographic purposes. The law categorically prohibits this kind of offense. To trick people into visiting websites they didn't plan to, files containing illicit photos are occasionally labelled improperly. There are certain provisions under the

Information Technology (IT) Act of 2000 to address current sexual exploitation of children. Section 67 B particularly lays out severe penalties for posting, viewing, or sending digital child pornography. Additionally, fostering, luring, or encouraging children to interact with one other online for sexually overt acts or in a way that might annoy a rational adult on an online platform is punishable by up to five years in prison and a fine of ten lakh rupees for a first offence, and up to seven years in prison for a successive offence. (The Information Technology Act, 2000, s. 67 B) Furthermore, online bullying (The Information Technology Act, 2000, s. 67 B (d)) and cyberstalking of women (Indian Penal Code, 1860 s. 354 D) are punishable under the Indian Penal Code 1860 (now section 78 of the Bharatiya Nyaya Sanhita, 2023)

Distribution of Erotic and Pornographic Material

One of the first types of data to be profitably made available over the Internet was sexually explicit content, which provides retailers of arousing and pornographic material with benefits such as media exchange including pictures, films, and live streams without the requirement for expensive shipments and worldwide access, approaching a much larger audience than physical stores. Printing or transferring pornographic content is punishable by a fine and confinement that may be as much as five lakh rupees and three years on first prosecution under the IT act of 2000.

However, on a second or consequent conviction, the offender will be subject to a fine and incarceration that may be as much as ten lakh rupees and seven years, respectively. (The Information Technology Act, 2000, s. 67) Further, anybody who willfully takes, distributes, or transmits a photograph of a person's private area without that person 's agreement infringes that person's right to privacy and may face up to three years in prison or a fine of two lakh rupees, or both. (The Information Technology Act, 2000, s. 66 E) Additionally applicable are voyeurism (Indian Penal Code 1860, s. 354 C) (now sections, 77) and showing pornographic items to women against their will (Indian Penal Code 1860, s. 354 A (iii)) (now

section 75) as defined and punishable under the Indian Penal Code 1860. The practice of "voyeurism" involves the observation, recording, or dissemination of a woman engaged in a private act.

3.5.7.4. Ransomware Attack

Ransomware involves the unlawful utilization of software that conceals the user's data or intimidates to make it public unless a ransom is paid to the criminal. By inserting a Trojan inside a valid file that the victim is misled into accepting or downloading, ransomware assaults are committed out. The WannaCry ransomware assault, which infected computers running windows and encrypted the data of its victims, spread pandemonium throughout the world. Bugs were used to mechanically disseminate this assault, with no assistance from the victim. According to section 66 A of the IT Act, 2000, the offence is penalized by a period of confinement that may exceed three years as well as a fine. (The Information Technology Act, 2000, s. 66 A) Extortion (Indian Penal Code 1860, s. 383) (now section 308) as made punishable under the Indian Penal Code 1860 also applies to this specific offence.

3.5.7.5. Spoofing of Emails and IP Address

Email spoofing is the technique of generating a falsified email account and transmitting emails that look to have come from a trustworthy source. Due to the ease with which the necessary data can be obtained online to create a forged email address, email spoofing is a popular cybercrime used to deceive the users. Therefore, before viewing an email or accessing any material, we should always verify the sender's email address. IP spoofing is used to disrupt a network, whereas email spoofing focuses on the subscriber. To make it appear as though the message came from a trustworthy source, the hacker typically transmits the target mail with a phony or faked IP address. This is intended to acquire the victim's account details and other sensitive data. When it comes to email and IP address spoofing, section 66 D of the IT Act, 2000, is applicable. Any individual who uses a

telecommunication gadgets or electronic asset to commit fraud by impersonating another person may be penalized with up to three years in prison and a fine of one lakh rupees. (The Information Technology Act, 2000, s. 66 D)

3.5.7.6. Phishing

Phishing is a type of cybercrime wherein users are tricked into giving away their personal credentials, such as passwords, credit card numbers, and financial data, by pretending to be a trustworthy body in online correspondence. It is one of the earliest kinds of cyberattacks but keeps getting more advanced over time. The IT Act makes no mention of the offense of phishing, but section 66 A (c) makes it a criminally punishable by three years in prison and a fine. (The Information Technology Act, 2000, s. 66 A(c)) Additionally, the offence of cheating and dishonestly inducing delivery of property (Indian Penal Code 1860, s. 415, 420) (now section 318, 303) as defined in the Indian Penal Code 1860 is applicable along with the section 66 A (c) of I T Act.

3.5.7.7. Financial Frauds/Scams

There has been an abrupt increase in different types of economic crimes throughout the world. These crimes include fraud in banking and corporate sectors, manipulation in stock markets, counterfeiting of currency, bribery, and embezzlements. A global survey carried on by Association of Certified Frauds Examiner (ACFE) had published its findings 'The Report to the Nation' in the year 2020. The report has revealed that in 125 countries nearly 2.504 cases of frauds had resulted into loss of US$3.6 bn.(A Report to the Nations ® Foreword 2 Key Findings 4 Introduction 6 How Is Occupational Fraud Committed? 9 Detection 21 Victim Organizations 28.)

3.5.7.7.1. *ABG Shipyard Scam 2016-2022*

ABG Shipyard company was incorporated in the year 1985. It was one of the important companies in shipbuilding and repair business in India. It was situated in Surat at Dahej in Gujarat. As per the report submitted by the CBI, ABG Shipyard

company and its directors were alleged to have cheated consortium of 28 banks headed by State Bank of India, to an extent of 23,000 crore. In the year 2019, a forensic audit was conducted by Ernst and Young. The investigation disclosed that the money taken as loan was deflected to other companies associated with ABG shipyard.(Forensic Accounting: An Investigative Tool to Combat and Prevent Economic Crimes | RostrumLegal.)

3.5.7.7.2. *Nirav Modi Scam 2018-2020*

The scam pertains to the issuance of a Letter of Undertaking (LOU) worth Rs. 10,000 crores fraudulently by the corrupt officials of PNB. It was reported to the CBI that LOU's worth rupees 2.8 billion was fraudulently issued by the PNB corrupt employees. Within a period of 5 months, the amount swelled to the tune of 14,000 crore. The entire scam was designed by Nirav Modi, the renowned diamond merchant in connivance with his other cronies.

According to section 66 C of the IT Act, anybody found guilty of illegally exploiting another person's password, electronic signature, or distinctive identification number faces a 3-year prison sentence as well as a fine that could reach one lakh. (The Information Technology Act, 2000, s. 66 C) The maximum sentence for using personation to commit fraud is three years in prison and a fine of at least one lakh rupees. (The Information Technology Act, 2000, s. 66 D)

3.5.7.8. Cyber Forensic Inquiry Vis-à-vis Right to Privacy

In accordance with Article 19 of the Indian Constitution, the right to privacy is a basic freedom. (The Constitution of India, art.19.) When information in digital formats is sent to forensic science analysts, there is a danger of privacy breaches. It makes sense to assume that forensic experts should have accessibility to anything that might be useful in finding the offender so that the aggrieved might receive justice. However, overwhelming many a time, the analyst takes not only the essential data but also all the sensitive data that is irrelevant to the case or is not valuable for it.

This information can be later applied to different ends. Therefore, there is frequently a chance of privacy violation during a cyber forensic inquiry. In India, it is necessary to establish some sort of governing body that will create a standard of practice and accredit forensic experts. This code of conduct may also include rules for the violation of a person's right to privacy if a disclosure of personal information puts that person's life in danger. Cyber forensics are governed by well-established worldwide organizations. The forensic science division of the Indian government may adopt those organizations codes of ethics.

It will facilitate a swifter investigative procedure. The International Society of Forensic Computer Examiners(The International Society of Forensic Computer Examiners. (ISFCE) is one such group that the Indian forensic department ought to join. In the subject of cyber forensics, it is among the most well-known organizations. The National Agreement on Crime of the Council of Europe(The Convention on Cybercrime, Budapest, 23. XI.) also systematically addresses cybercrime. It is a multilateral agreement that provides provisions for both cybercrime and invasions of privacy. Additionally, it has attempted to reconcile and unify the process of gathering cyber forensic proof in cybercrime while simultaneously providing strict codes and rules for defending people's rights to privacy.(The Convention on Cybercrime, Budapest, 23. XI. European Treaty Series No. 185.)

3.5.7.9. Fight Against Digital Crimes

The future of the next generation is changing in the modern world. Information Communication Technologies (ICTs) are a crucial tool for national success and advancement, and the internet in particular is a driving force behind improvements in the international, national, and local economies as well as in fields like academics and healthcare. To enhance earnings, these technologies must be used responsibly, which eliminates any action that is against the law. Cybercrime diminishes or even demolishes innovation, inventive resilience, and innovation-driven economic expansion in light of the significant advantages that ICTs provide for

progress.(Emile Loza de Siles (2015) The above-mentioned reasons make the battle against these practices a top concern.

3.6. Concluding Remarks

After the 2008 amendment, the IT act has emerged essential for unravelling cybercrimes yet, due to technical improvements and offenders prompt and crafty minds, they occasionally manage to evade the reach of the law. Almost all the nation's police agencies now have cyber units. In almost every law enforcement agency in India, there is a cyber-crime investigation unit where the cops and cyber forensic professionals work to fight criminal activity using a variety of computer forensics technologies and a methodical process of search and seizure, collection, evaluation, and publication. In one of the landmark cases (Dilip Tulsidas Shah v. UOI W.P.C. No. 97 of 2013) it was noted that conventional inquiry tactics are nonetheless being pursued, resulting in police abuse of people despite being inadequate to handle complicated cyber-crimes. Since Tulsidas, numerous other writ petitions have been submitted to request the creation of an acceptable legislative structure for the efficient detection of cybercrimes. (Dilip Tulsidas Shah v. UOI W.P.C. No. 97 of 2013)

CHAPTER III

HISTORICAL DEVELOPMENT OF FORENSIC SCIENCE WORLDWIDE

1. Introduction

When and how did forensic science evolve? This issue deserves our consideration since knowing the background of forensic science greatly improves our comprehension of it today. Forensic science is considered as science used in the service of justice. The prevention and identification of offenses targeting the individual's person and assets play a significant role in determining his or her degree of safety. The goal of forensic science is to help the jury reach a verdict on a defendant's culpability or innocence in relation to the criminal act they are accused of committing. Prior to very recently, forensic science was only routinely applied to criminal inquiries of grave crimes like murder or heinous crimes against people.

Medical experts handled most of these examinations, that were generally covered under the domain of forensic medicine or medical jurisprudence. The genesis of this discipline has varied significantly among nations, with the level of crime's prevalence undoubtedly serving as a major deterrent.(R. Society & Society, 1945) Given the expansion and specialization of forensic studies over the 20th century, it is crucial to recognize the contribution of medico-legal professionals to the growth of forensic science. Forensic medicine is a subject that predates forensic science; doctors attended trials in the seventeenth and eighteenth centuries.(Watson, 2010)

It took until well into the twentieth century for forensic science to emerge as a distinct scientific field. In the early years of the century, medicolegal professionals conducted a diverse variety of technical and analytical forensic tests and persuasively conveyed these in courtroom proceedings. It now appears quite strange that physicians were engaging in such practices, which were ostensibly outside the scope of their official duties. This illustration emphasizes how crucial it is to map the twentieth-century specialization of forensic specialties. A crucial step in the advancement of forensic science was the separation of forensic medicine and forensic science. This separation did not occur simply because a given forensic realm innately belonged to either science or medicine. Negotiation and agreement of definitions and official categorizations was required.

It is no longer essential to defend the notion that technology and science are cultural goods that should be examined in the identical manner because it has been established as the accepted wisdom in the historical memory of science and technology during the past forty years or so. The denial of technological determinism, or the idea that innovation steers nation or has vital implications on society, in favor of a greater nuanced perspective that perceives the connection between technology, scientific knowledge, and civilization as having multiple facets, is at the heart of ongoing perspectives in the history of science, even though correlations have changed over the past thirty years.

Such a strategy encourages us to regard technological and scientific advancements equally, searching for similar sorts of fundamental explanations for accuracy and mistake, of successful and unsuccessful technological advancements. We should be cautious about blindly adopting claims that forensic procedures based on acknowledged science are inherently superior to those not backed up by science. We should consider the methods that were deemed to be trustworthy and effective in the era, rather than evaluating them in light of current perceptions of the reliability of science. We cannot be assured how a technology or science methodology will be adopted and employed since humans are incredibly

innovative, notwithstanding the capabilities of specific techniques and the ways in which a specific kind of subscriber may be positioned in a software's layouts.(Douglas, 2012)

This reflects the constant worry that scientific development and technological advancement that can be utilized to fight crime could also be employed for nefarious purposes. A fundamental concept of modern science history is that progression cannot be solely linked with science to avoid adopting a "Whig" perspective on history.(Butterfield, H. (1995). The historical "science and literature" culture, which is primarily associated to the expanded field of research in science and technology and is populated primarily by scholars who study English literature and history of science, serves as motivation for the examination of the connection between detective imagination and forensic science.(Willis, 2014)

2. An Overview of the Development of Forensic Science Worldwide

2.1. Inception of Forensic Science in United Kingdom

2.1.1. The Bond Connecting Law and Science

We start by looking at how the bond involving science and law affected the growth of science-based knowledge and how early reverberations of this connection went on to show up in the Victorian era courtroom reality and continued till the twentieth century, where emerging forensic experts' testimony witnesses struggled with their courtroom presentations. Seventeenth century onward, an array of epistemological differences that are significant for both the law and science were formed.

They involve the ideas of facts and proof particularly substantial evidence, definite and reasonable understanding, witnessing, and the testimony of scientific experts. Epistemological classifications in science and law are intertwined and mutually productive.(Filosofie , 1983.) The idea of a witness with expertise was largely formed in the seventeenth century, when a person of science started to be trusted as a witness.(Shapin, 1995) Evidence, proof and facts lies at the heart of both law and science, and it is created and molded in each.(Shapin, 1995)

Core epistemological classifications were employed to assert command and prestige and later in the nineteenth century became crucial hallmarks of professionalization. However, these classes have become so naturalized that we no longer see their historical context. An essential component of the professionalization of science in the nineteenth century was the capacity to exert control over the creation of information about the world around us. A similar tactic was used throughout the time of professionalization of medicine, whereby assertions of a scientific foundation for medical understanding were used to support aspirations to obtain power and prestige. Important factors that contributed to the professionalization of science and medicine were the development of the witness of expertise position. Witnesses with expertise frequently discovered themselves in the thick of heated disputes for power in the courtroom, a phenomenon that peaked in the middle to late nineteenth century. These kinds of issues did not go away in the 20th century. As a result, medico-legal specialists and the forensic analysts developed ways to establish their credibility in the court during cross interrogation and to tackle with the ancient epistemological frameworks of facts, data, proof, and probability offered a seamless transition from the 18th to the 20th century.

The requirements of an adversarial court system clashed with the assurance of scientific expertise in the hands of trustworthy scientific witnesses. Experts who testify in the courtroom need to be well-versed in delivering evidence and keeping their cool under intense cross-questioning. The capacity of the scientist to testify in the courtroom, as well as the established reliability of a scientific procedure, was a crucial factor in establishing and retaining legitimacy. The use of handwriting analysis as proof is a classic case of a forensic method being embraced by the courts. Many people, including scientists, found it troubling that they could have to face off against each other in court as experts for opposing sides.(A. Adam, 2015)

Some experts who testified in court clearly enjoyed testifying as witnesses and had created suitable assisting methods, while others found testifying to be a challenging and not altogether welcome aspect of the profession. However, submitting written

testimony without being in court also has its drawbacks. Several medico legal experts and forensic analysts had a reputation for being standouts in the courtroom; in fact, several of the fresh batch of forensic scientists hired to fill the openings in the 1930s did so partly because of their impressive track records in the courthouse. Others, however, found the demands of testifying in a court of law to be at odds with the meticulous, professional nature of their scientific tasks and so created techniques to help them function amid pressure.(A. Adam, 2015)

2.1.2. Data, Facts Ethics, and Expertise

The notion of 'fact' and the related idea of 'witness' originated in the legal discipline as opposed to the scientific disciplines. Certainly, we cannot establish facts without a recognized, qualified person to attest that a given thing is a fact. The concepts of "fact" and "substance of fact" originated in the legal field but have since spread to other domain to the point that they were accepted into mainstream British scholarly and cultural life throughout the late 17th and early 18th centuries. Formed in 1665, the Royal Society an organization for scientific research in the UK engaged in explaining and organizing natural occurrences and facts, and it is widely acknowledged that this early work contributed significantly to the development of the notion of fact as an epistemological group in scientific research.

Among the early members of the Royal Society, Francis Bacon (1561-1626) played a pivotal role. Indeed, the early Royal Society's scientific agenda was influenced by the Baconian mission of expanding understanding of science by meticulous 'fact' collection. The concept that 'facts' were objects in the natural world that could be gathered and recorded by a trustworthy witness was central to Bacon's contributions to the introduction of 'fact' into the natural sciences, where he worked as a lawyer, historian, and scientist. Although 'fact' was not an unchanging idea, it was malleable. The concept of fact discovery was often reimagined by academic fields to fit their own ends.(Filosofie, 1983, p. 7)

A 'fact' in the context of the law is any observable act committed by a human being.(Filosofie, 1983, p. 9) It was the job of the jury to determine "matters of fact," whereas the responsibility of the judge was to interpret the provisions of the law. The ease with which establishing facts in the legal context could be transferred to other contexts was due to this familiarity of determining facts. In the context of law, "fact" meant "act," therefore the term took on a more dynamic sense than it did in its first scientific incarnation, when big Baconian operations like collecting and categorizing objects from a relatively passive natural world were its hallmark. The concept of knowing something with certainty came first, followed by the concept of knowing something with certainty about individuals. To arrive at "morally definite" decisions in "matters of fact," the English judicial structure of the time required the participation of jurors, judges, witnesses, and lawyers.(Filosofie, 1983, p. 30)

The revolutionary experimental discipline of the Royal Society, with critical chemist Robert Boyle as its prototypical representative, was distinguished by its emphasis on analysis and empirically created facts. Witnesses "whose testimony would be assessed based on a set of lawfully determined standards of reliability, such as possibilities, capacity, probity, ability, faithfulness, rank, expertise, and repute" verified scientific truths in the same way that lawyers did.(M. Jones, 2003)

Notably, natural scientists accepted frameworks of seeing truths previously developed in law and history, enabling them to understand the legal vocabulary used to communicate such conceptions. Thus, scientific virtuosi, as seventeenth-century scientists were referred to, emphasized witnessing, unbiased, and caution, which meant they weren't required to justify their utilization of the word 'fact' since it had previously been in general usage in other sectors of life. Science specialists of "middle rank" were just as trustworthy as gentlemen, thus having a gentlemanly background helped boost trustworthiness.(M. Jones, 2003, p. 112)

Moving ahead to the late nineteenth and early twentieth centuries, there are many examples of scientists of "middling rank" becoming reliable experts. By the second half of the nineteenth century, the separation underlying facts and values had been established, and science had gained supremacy over the process of fact-making. Over the course of the past two centuries or more, the dichotomy of truth and value had been a central issue in the fields of law and science, and the witness of expertise position has flourished as a result.(M. Jones, 2003, p. 139)

Making this distinction and committing itself wholeheartedly to the concept of value-free, fact-based science is one of contemporary science's greatest achievements. Like the men of law, the men of science could portray their knowledge-making pursuits as objective and apolitical.

Forensic investigators and pathologists in the 20th century needed to be able to provide data and their professional judgement on such findings while maintaining an air of objectivity and neutrality to be credible witnesses in court. Consequently, professionals in the fields of science and law are now widely regarded as the most reliable sources of information. Their conclusions are considered objective rather than the outcome of subjective evaluation.(C. J., 1994. One of the unique aspects of expert witnesses is that they are allowed to form explanations for the cause of past events based on the facts presented to the court rather than simply presenting the facts themselves.(Barnes, 1990)

Although Roger Smith's study focuses on a specialist witnessing in the latter half of the twentieth century, his evaluation of the ways in which experts must submit to the separation between facts and opinions is highly applicable to previous expert witnessing, with the primary distinction being the increased prevalence of written witness assertions in court. It goes without saying that the fact that specialists have a perspective shows that facts don't speak by themselves and need elucidation.(Barnes, 1990, p. 65) For their testimony to be understood by others outside of their field of expertise, expert witnesses are trained to distinguish

between facts and views. According to Smith, most forensic criminalistics and pathologists believe that qualified witnesses are unanimous on the same facts, hence they do not see an issue with differentiating truth from opinion.

Reporting facts in a manner that other professionals would agree with is a mark of professionalism.(Barnes, 1990, p. 66) However, the specialists he surveyed, all acknowledged that there would be reasonable disagreements about the most plausible explanations. Despite this, they were under the impression that they would find common ground if they were given the chance to talk openly about their differences. In other words, given the chance, they may transform speculation into hard evidence, albeit through a series of probabilistic assertions. So, an acceptable method may lead to an acceptance, but the adversarial system played a major role in keeping the two sides apart. According to them, "a sharp distinction between fact and opinion is imposed by the legal setting," and "provided probable assertions are opened up into unshared declarations of opinion."(Barnes, 1990, p. 67)

Experts who testified in Smith's study generally agreed that disagreements over the evidence were not legitimate, but disagreements of opinion were, and that the adversarial framework was largely to blame for driving a division within facts and opinions, making it difficult for experts to reach a compromise on opinion.

2.1.3. Probability: The Moral Assurance that comes from Knowing for Sure

The issue of probabilistic assertions is linked to the production of facts, the separation of facts from values, and the differentiation of facts from views. “Probability and Certainty”, the title of Shapiro's seminal book, alludes to the fact that the two concepts are inextricably intertwined. Certainty has important ethical implications.(Filosofie, 1983.) There was "a common set of assumptions about the nature of truth, the methods for attaining it, and the degree of probability or certainty that might be attributed to the findings produced by those methods" across many fields, including law, science, religion, history, and others.(Filosofie, 1983, p. 3)

In the latter part of the 17th century, people began to conceptualize knowledge as being on a continuum from absolute to relative certainty, with ‘moral certainty' at the most definite end and speculation and view at the other.(Filosofie, 1983, p. 3) In fact, the surprise of observing experts argue in court over their differing ideas in the nineteenth and twentieth centuries highlights ongoing assumptions of the moral character of certain information and the protectors of information, namely men of science.(Liebenau, 2009) Over time, probabilistic thinking replaced absolute facts as the dominant paradigm. This shift may be attributed to the emphasis on empirical research within the scientific community, which in turn suggests that the empirical sciences have become more distinct from mathematics in their pursuit of certainty.(Liebenau, 2009, p. 9) A major issue for scientific specialist testifiers who had to determine the credibility of their evidence was whether they could make accurate assertions about concepts that they had not personally seen. In the seventeenth century, this was a major problem, especially for those who wanted to accurately portray history. In the seventeenth century, "probability" came to signify "an acceptable degree of evidentiary backing for a contention that was not certainly true" in the context of scientific knowledge.(M. G.- Nuncius,1997.)

Witnesses with expertise from the scientific community still have challenges when it comes to dealing with probability and ensuring that probabilistic logic with respect to evidence is made clear. The moral component is still crucial. If a modern statistician were to discuss probabilistic inference in relation to moral certainty, we may be a little taken aback. However, forensic scientists have written a lot of remarks on the moral characteristics of knowledge, reality, and expertise, and by extension, the moral values of forensic experts. According to Smith, scientists have a deep moral dedication to the 'truth,' which is seen as a trait one acquires via working in the field.(Barnes, 1990, p. 70) Characteristics of the expert make it possible for a scientifically educated person to act honorably in a hostile environment when there is less of a dedication to "the truth."(Barnes, 1990, p. 71)

2.1.4. The Evolution of the Scientific Expert Witness

Scientists, technologists, and legal academics agree that testimony has played a vital role in shaping the science-law connection throughout history and continues to do so in modern discussions of forensic science. The testimony of witnesses, especially experts, plays a crucial role in the British-American judicial system. Both Shapin and Schaffer, and to a lesser extent Shapiro, defend the legitimacy of the scientific gentleman of the seventeenth century as a witness to a logical fact.(F. A.- Nuncius, 1987.) The subject of scientific testifying has been drawn to the court's notice on occasion, despite the fact that this does not correspond to how people now conceive the connection between experts and facts in the modern world.

Robert Boyle (1627-1691), often recognized as the forefather of the modern scientific witness, played an essential part in the evolution of facts, evidence, and probability. Foreshadowing an important aspect of Enlightenment thought—the shift from men of science viewing themselves merely as intellectuals to transforming into actively engaged in empirical examinations of natural phenomena—Boyle is recognized as an important contributor in developing a method of experimentation where effectively credentialed others could witness and concur on the facts of a scientific phenomenon.(F. A.- Nuncius, 1987.) The technique of science relied on eyewitness accounts of investigations, either conducted in person or recorded in a written form for later reference.

Whatever the case, a consensus on a set of norms was necessary, and Boyle emerged as a key person around whom a consensus on methods might form. His work demonstrates that in addition to the content organization of scientific experiments, consensus on acceptable witnessing technology and the reliability of the testifying agent are crucial to the growth of creating and consenting to scientific truths. This has been crucial during the many years of collaboration between the legal and scientific communities.

Numerous forensic medicine and forensic science literature, as well as two English-language versions of Gross's “Handbuch für Untersuchungsrichter” (Handbook for

Examining Magistrates), had been published by the latter part of the initial decades of the twentieth century.(Willcox, 1922) One notable example is the twelfth edition of "The Principles and Practice of Medical Jurisprudence" by Alfred Swaine Taylor (1865), which was published to celebrate the book's centennial.(A. T.-J. of C. Science, 1871.) While penning or editing a book considered authoritative had its perks, the author or editor was responsible for maintaining the work's credibility. The author of such a scientific publication may find his "virtual witness" testimony used versus him in court. The expert's own textbook, which he or she may have authored or edited, may be used as a scientific authority by opposing counsel to have the expert contradict himself in court. The credibility of the expert's testimony and the reliability of the book were both damaged by the author's decision to have him appear to dispute his own writings.(Simpson, 1964) There was a moral weight to bearing witness. The concept of the "ideal scientific observer and reporter" borrowed elements from the role of a witness in a court of law.(M. Jones, 2003, p. 118) Competence, knowledge, professionalism, and honesty were essential qualities. Knowledge was valued more than position, and practical experience and affiliation with a professional organization were considered just as significant as formal education.(Watson, 2010, p. 47)

2.1.5. Keeping Jurors and Witnesses Apart

The development of the function of the witness, and particularly the expert witness, was crucial to the delineation of the jury and witness roles, which had previously been combined. Witnesses made up early juries, in communities where everyone knew one other, individual witness were often not considered essential. The role of juries evolved from that of witnesses to that of fact finders during the 16th century. The members of a pre-modern jury were chosen because of their familiarity with the subject matter or their skill in the field involved. Court experts and specialized juries of craftsmen were utilized to determine craft disputes, with the combined expertise of the two sources serving as the foundation for a judgement.(C. J., 1994.

Over the course of the centuries between the sixteenth and the eighteenth, the role of expert witnesses in court proceedings shifted from that of advisors to that of partisan expert witnesses, and they were also given more leeway to draw conclusions from the evidence they presented.(Dwyer, 2007) There was minimal room for public debate thanks to the court's reliance on specialists and special juries throughout the initial stages of this period. Although this trend would not fully materialize until the nineteenth century, by the end of the eighteenth century, specialists were being pitted against one another in courts. As time went on, attorneys began to view expert testimony with skepticism due to its partisan nature, even though it was generally acknowledged that experts would have to provide judgements on causative concerns in addition to mere facts.(Dwyer, 2007, p. 118) Over the course of many centuries, society shifted from using juries as witnesses to using juries devoid of lay people but relying instead on expert witnesses to offer advice to the court, and eventually to the current system of using expert witnesses with a clear political bias. We may all agree on how important it is to have fair trials with unbiased jurors, yet far into the twentieth century, some people still like the notion of an expert witness advising the court.

In the early days of expert witness testimony, doctors were often consulted by Coroners' courts to determine the reason of death and played a pivotal role in confirming death for the purposes of state executions.(C. J., 1994, p. 21) Many people consider the civil case *Folkes v. Chadd* (Folkes v. Chadd, (1782) 3 Doug KB 157.) from 1782 to be the first time wherein scientists were called as witnesses in a legal proceeding. This case was significant in the connection between the legal and scientific communities because it allowed expert witnesses to testify based on their expertise even if they had not personally seen the events in question.(Golan, 2004) The expert witness as we know it today emerged in the eighteenth century and matured in the nineteenth, when the current model of trial by jury emerged and the functions of witness and juror became separate.(Arapostathis & Gooday, 2013)

2.1.6. The True and Erroneous Nature of Evidence: Establishing Credibility in Court

Despite its flaws, the courtroom was an important venue where scientists could assert their credibility and where new scientific methods were either approved or dismissed; hence, it was a site where knowledge of science was created. It was possible to observe the methods scientists used to 'perform' scientific authority in court via their testimony. Furthermore, the processes associated with scientific expert testimony in the late nineteenth and early twentieth century disclosed fascinating features of the epistemological standing of diverse forensic disciplines and procedures and how they were given epistemological authority. Forensic methods adapted for use in the legal system, as opposed to those based on preexisting scientific knowledge is where Saks believes a distinction may be made.(M. S.-Wash. & L. L. Rev., 2000.)

The former group included disciplines and methods devoted to establishing the identity of a person, such as fingerprinting, mark recognition, and assessment of handwriting, all of which were grouped together as "police technique" in Britain by the middle of the twentieth century. In the 1920s and 1930s, when forensic science was taking off in the UK, fingerprinting was widely regarded as a problem-free method. Although the early and mid-century years of the twentieth century did not put the credibility of certain forensic techniques under the microscope, this was changed as the century progressed.(D. C.-B. Sci. & Tech. L. 2009.)

Whatever the case may be, a British forensic expert from the 1980s attests that despite specialization in the forensic sciences, forensic scientists of the twentieth century had to acquire their specialized abilities together with the skills of identifying and employing any approach that suited their goal. When it came to electricity, water, gas, patents, environmental damage and contamination, insurance, and of course, criminal cases, the courtroom was a crucial site for the implementation of science in the late Victorian era.(Hamlin, 1986) Witness

testimony from experts was equally crucial in both civil and criminal proceedings. Expert witness possibilities, for instance, were abundant in patent infringement cases.

Therefore, it should come as no surprise that the media, popular culture, and legal circles of the middle to late Victorian era saw the system of delivering scientific expert witness in civil and criminal proceedings as extremely challenging.(Gooday, 2008) The outcomes of Smith's study are generally in agreement with the viewpoints of those who believe that the issue was caused by the adversarial nature of the legal system, which pitted scientists who were summoned for prosecution and defense against each other.(D. C.-B. Sci. & Tech. L., 2009, p. 486)

In the late Victorian era, however, the thought of a few scientists reached a degree of sophistication in regard to the issue, a strategy that saw that there was no easy 'correct answer' and no simple remedy.(D. C.-B. Sci. & Tech. L.2009, p. 488) Witnessing in court was a lucrative profession for many scientists, but it also brought with it the stigma of being "hired guns" whose testimony was skewed to benefit the side that paid them.(J. M.-Vill. L. Rev., 2007.)

The forensic scientists of the twentieth century continued to face additional objections, including the following:

1. How could juries draw a conclusion when one scientific viewpoint opposed another scientific opinion, given that expert witnesses could give feedback based on their scientific judgement as in contrast to matters of fact, which was the realm of the ordinary witness.
2. There was also the issue that some scientific expert witnesses failed to properly put together or present their testimony. Even though a scientist has impeccable credentials, they may struggle to serve well as a witness in court. Experienced solicitors often manipulated the testimony of honest witnesses on purpose.(D. C.-B. Sci. & Tech. L. 2009, p. 782)

2.1.7. A Constant Legal Battle Between Opposing Scientific Experts

The Palmer case serves as a pertinent illustration of the extensive historical scope and contentious character of expert testimony and publicized scientific controversies. It exemplifies the predicament of scientific expert witnesses. The case of Dr. Palmer's poisoning with strychnine, which was dubbed as 'the crime of the age', serves as a prime example that highlights several key causes why scientific testimony in legal trials was perceived as a challenge. This case has garnered significant interest and is appropriately acknowledged.(Emsley & Watson, 2004)

Due to the prominent status of the case, the dispute between the prosecution and defense regarding the identification of strychnine during the post-mortem examination was widely observed and had the capacity to negatively impact the credibility of the medical and scientific professionals associated. The Palmer trial holds the distinction of being the initial case of strychnine poisoning to be tried in the United Kingdom. A total of 39 expert witnesses provided compelling proof. Dr. Alfred Swaine Taylor was among the medical professionals who conducted the postmortem examination while representing the prosecution.

The search for strychnine was unsuccessful, however, the hypothesis was posited that the substance had undergone absorption into the body's tissue and subsequent chemical alterations, rendering it undetectable. Notwithstanding, the defense contended that Taylor's failure to detect the presence of strychnine serves as evidence of its absence. The theory posited by Taylor regarding the presence of strychnine was refuted by William Herapeth, a distinguished academic in the field of chemistry at Bristol Medical School. Herapeth deemed Taylor's theory to be a mere fabrication for the purposes of the trial, contending that had strychnine indeed been present, Taylor would have been able to detect it.

The trial's conflicting scientific proof had already elicited a negative response from the public. The trial's scientific and expert witnesses exhibited a lack of credibility, as they were perceived to have demonstrated incompetence, fabricated hypotheses, and displayed bias in their conduct.

2.1.8. The Practice of Expert Witnessing During the 20th Century.

The aforementioned issues persisted throughout the 20th century. The Frye standard, which was implemented in the United States during the 1920s, and the Daubert test, which was introduced in the 1990s, were established, at least in part, to address the challenges associated with expert testimony. Specifically, these standards aimed to regulate the admission of scientific evidence in legal proceedings, albeit exclusively within the United States.(Reece, 1997) During the latter half of the 20th century, P. Huber popularized the term "junk science," particularly in North America, to refer to the intentional promotion of fraudulent scientific information within legal proceedings.

There exists a substantial body of modern critique regarding the criteria for scientific substantiation utilized within the criminal justice system. A group of 116 scientists recognized that legal disputes could have a negative impact on their professional reputation. Therefore, they sought to devise effective tactics for handling cross-examination to prevent any significant courtroom conflicts from arising. The focus was shifting towards policing and scientific detection as the most vulnerable aspects in the narrative of forensic analysis, rather than the court's delivery.

The Home Office's recently established forensic laboratories, situated within the formal framework of the criminal justice system, have contributed to the cultivation of a prosecutorial mindset.(Barnes, 1990) This factor bolstered the prosecution's forensic advantage, potentially undermining the credibility of opposing expert witnesses in legal proceedings. Nonetheless, a persistent risk existed whereby a scientist collaborating closely with law enforcement may succumb to the influence of police intuition and interpret their scientific findings accordingly. This issue was acknowledged by certain forensic scientists.(Barnes, 1990, p. 248)

2.1.9. The Intersection of Technoscience and Criminal Recognition Advances in Technology.

The idea of "technoscience" is especially helpful for comprehending how technological innovation may be seen as fostering the growth of detection and policing since it explains how scientific policing relies on integrating proper supporting techniques. Along with advances in transportation, media, and communication technology, scientific policing has included several concepts borrowed from the field of scientific criminology, including, to a lesser degree, the study of offender looks and physiognomy.

The infamous Crippen case of 1910 is illustrative of a wide range of issues related to technology and science. Since the use of wireless telegraphy in tracking down Crippen was widely celebrated as the initial instance of its central role in a detention, this case provided an opportunity to examine the function of the press in illustrating the application of communications and media technologies in policing, as well as the role of offender physical appearance in the construction of guilt.(Studies, 1996.) The use of forensic scientists and medical professionals in the Crippen case demonstrates the full breadth of technologically informed law enforcement.

The other side of the coin, the illicit application of science and technology, must be considered when discussing the utilization of technology in scientific police work. Everyone, understandably, is worried that offenders would quickly adapt to and abuse any novel technology that was offered. An examination of the implementation of technologies in scientific law enforcement necessitates an exploration of the corresponding aspect, which is the utilization of science and technology by perpetrators of crime. The concern regarding the swift adoption of novel technology by offenders and its potential exploitation for illicit purposes was a prevalent and pragmatic apprehension. During the first half of the twentieth century, the utilization of technologies facilitated the incorporation of the phrase "scientific" into contemporary policing practices.

The adoption of the term 'scientific' as a metaphor to denote a contemporary and forward-thinking approach is contingent upon the availability of supportive technologies. The conventional notion of the 'linear model' of scientific and technological advancement, which posits technology as a mere application of science that flows unidirectionally from scientific breakthroughs, has largely lost its popularity within the realm of science and technology studies.(D. C.- Nuncius, 2008.) The crucial aspect to note is that the rejection of a linear model underscores the notion that clear-cut demarcations among science and technology are not conducive. Rather than being viewed as separate entities, science and technology are more appropriately regarded as intertwined components of what is commonly referred to as 'technoscience'.(Rocque, 1992)

The term 'scientific' was frequently employed to indicate a contemporary and forward-thinking approach, however, it should not be conflated with the notion of being inherently progressive. The definition of what is deemed as 'scientific' in various disciplines is subject to change and is not necessarily universally regarded as favorable, as it can vary across disciplinary borders and over time. The advancement of scientific policing and scientific detection was accompanied by the emergence of various contentions in support of these practices. The perception of a technique or technology as scientific was often contingent upon its novelty. The rise in popularity of 'scientific management', a systematic, centralized, progressive, and modern form of organization, was not coincidental.(Bluedorn, 1986)

While scientific support to uncovering crimes and forensic science discourse seldom make overt allusions to scientific management, it is evident that the state-of-the-art scientific research facilities depicted in photographs or described in autobiographies and popular works on forensic science during the mid-twentieth century were unequivocal tributes to scientific management. The field of forensic science emerged as a discipline that could be systematically organized and approached in a scientific manner.(Wilson, 1959)

2.1.10. The Emergence and Increasing Prevalence of Fingerprinting as a Method of Identification.

The narrative of the ascent of fingerprinting as a technology for identifying criminals has been recounted on numerous occasions, with several noteworthy historical accounts having been published in the current era.(Sengoopta, 2003) After the implementation of reliable recording procedures, fingerprinting emerged as a viable technology for forensics and gradually supplanted Bertillonage. This approach was perceived as a cost-effective and straightforward means of achieving identity verification, and was widely regarded as an invincible technique, thereby alleviating issues surrounding the identification of criminals. Undoubtedly, individuals have long been intrigued by the import of the unique ridge patterns located on their fingertips. Historical indications suggest that these ridges served as a substitute for endorsements in ancient times. Therefore, it would be an overstatement to assert that they were "discovered." Fingerprinting has been identified as a pivotal aspect in various fields.

During the period of British imperial dictate in India, a dependable technique for recognition was developed. Following the Indian Rebellion, also known as the Sepoy Mutiny, in which significant loss of life occurred on both sides of the conflict, the British government assumed control of India from the East India Company. According to Sengoopta's argument, the British in India placed an increased emphasis on race, particularly as they sought to delineate Indian racial distinctions through the lens of the caste structure. This ostensibly more "scientific" approach was prompted. The cause of the decline in the use of the Enfield rifle by the British East India Company was primarily attributed to the 1857 Sepoy Mutiny rather than scientific factors.(Sengoopta, 2003, p. 42)

The inception of the practice of organized fingerprinting for civil identification in India can be traced back to the contributions of William James Herschel (1833-1917). The British colonial governance was characterized by a notable lack of

confidence in the indigenous population. The act of repudiating contracts after their signing was a prevalent occurrence. As a result, in 1858, Herschel made the decision to request the signature of a local contractor using a handprint.

The objective was to intimidate the contractor into refraining from renouncing their signature at a later point in time, rather than having a definite anticipation that the handprint would be utilized for the purpose of identification. Subsequently, Herschel's intrigue with fingerprints intensified, prompting him to amass various instances of fingerprints and scrutinize their distinguishing features. He advocated for the utilization of fingerprinting as a means of validating agreements on contracts amid disruptions related to the indigo industry. This industry was characterized by numerous instances of oppressive behavior on the part of plantation owners towards local growers. The observation of a significant volume of legal disputes pertaining to contract repudiation further reinforced the individual's conviction that fingerprints constituted a viable solution. Initially, the individual's attempts were focused on the authentication of signatures on legal documents and the verification of pensioner identities. There existed a pervasive sense of doubt regarding the ongoing receipt of pension funds by individuals impersonating the original beneficiaries, even in cases where the latter had passed away several years prior.(Sengoopta, 2003, p. 73)

The aforementioned trials yielded positive outcomes as they led to a noteworthy reduction in instances of deception and renunciation. A significant facet of Herschel's work pertained to his extensive compilation of fingerprints, which he had amassed over a prolonged duration of time. He conducted self-experimentation and demonstrated that his fingerprints remained unaltered from 1859 to 1916. Although lacking conclusive proof, the individual possessed a substantial amount of evidence to substantiate the assertion that fingerprints are distinct to each person and remain constant throughout their lifespan. This evidence was of great significance. The dependability of fingerprint-based systems is contingent upon the acceptance of these presumptions as justifiable.

The subsequent significant advancement in the history of finger prints pertains to the contributions of Henry Faulds (1843-1930), a Scottish missionary with medical training and a strong interest in Darwinism, who was employed in Japan.(Sengoopta, 2003, p. 79) Encouraged by his study of fingerprints on ancient pots and hoping to use fingerprint ridges as indicators of race, he initiated a collection of fingerprints, even soliciting samples from around the world.(Sengoopta, 2003, p. 80) Faulds corresponded with Nature, a preeminent scientific journal in Britain during that era, explicitly indicating the prospective utility of their methodology in the realm of criminal identification.(Nature, 1880.)

Juan Vucetich is acknowledged with developing the earliest functional fingerprint system for the purpose of criminal identification, which was implemented in Argentina in 1891.(Wayman et al., 2005) In 1901, the system devised by Sir Edward Henry (1850-1931)(Wayman et al., 2005) was implemented by Scotland Yard. Henry played a pivotal role as the concluding and noteworthy character in the narrative of British fingerprinting. In 1873, he commenced his career in the Indian Civil Service in Bengal and gradually progressed to attain the position of Inspector General of the Bengal Police in 1891.(Sengoopta, 2003, p. 121) Henry's contribution to the Bengal Police was the implementation of anthropometry, a technique already employed by Indian anthropologists to assess caste differences.

However, Henry's focus was on utilizing this system to study the "criminal tribes," a group that was resulting in major worries to the British administration.(Sengoopta, 2003, p. 126) The fingerprint system for categorization was announced by him in 1897.(Cherill, F.R. (1954).The aforementioned development dealt a fatal blow to the practice of Bertillonage in the context of British India, leading to its rapid dissemination. Henry received significant assistance from his two aides, Azizul Haque and Hem Chandra Bose. Haque made significant contributions towards the development of the system, to the extent that he may be considered as the original creator.(Sengoopta, 2003, p. 143)

The task at hand in fingerprint searches involved devising a methodology to effectively utilize the ridge patterns present on all ten fingertips, including loops, whorls, arches, and composite patterns, for the purpose of correctly categorizing a given set of prints. The aim was to ensure that the classification system produced feasible record counts for each of the groups. The technology of fingerprint recognition entails the categorization of distinct groups, which may not be uniformly distributed across all possible classifications within the population. This presents a significant obstacle in the field. The Henry classification system is a highly sophisticated method of sub-categorizing fingerprints into more than 1024 distinct subcategories.(Sengoopta, 2003, p. 213)

Naturally, the subcategories exhibit significant variations in size, ranging from a small number to a large number. Substantial subcategories have the potential to be further subdivided. The efficacy of the system is not absolute and is contingent upon the precision of the initial categorization. If a misclassification occurs, it could be further exacerbated by subcategorization. There exists a trade-off between the dependability of a system and the expeditiousness and simplicity of locating a corresponding item. According to Wayman, manual systems utilizing this classification exhibited approximately 75% validity, and the implementation of thorough operator training served to reduce indexing errors.(Wayman et al., 2005, p. 25)

The identification of a match was achieved through manual comparison of fingerprints using a magnifying lens, to compare them to the search individuals recognized by the system.(Wayman et al., 2005, p. 27) If a matching card was present, it was probable to be located, albeit not necessarily. In the event that the initial prints were erroneously categorized or improperly stored. The system in question exhibited fallibility to a significant degree. It is important to note that the Henry system bore resemblance to Bertillon's anthropometric system in that it depended on comparing information of a suspect with that stored in the database to determine if the suspect had prior interactions with the law enforcement agencies.

Thus, both methods were utilized for the purpose of detecting repeat offenders. The Henry classification system was dependent on the ability to acquire a comprehensive collection of "ten prints" from an individual under suspicion. Therefore, it was not a viable method for associating a suspect with a particular mark left at the spot of a crime. The aforementioned procedure was dependent on the capacity to correlate a concealed impression, or impressions discovered at a location of criminal activity to the impressions obtained from a specific suspect.

The Henry framework served as the foundation of the initial computer systems utilized in fingerprint identification, which were implemented starting in the 1960s. While these methods may effectively address search errors, they are not capable of resolving initial classification errors.(Wayman et al., 2005, p. 28) The advent of computing technology, the discussion of the longevity and dependence on human skill of the system, which was originally developed by a British colonial police official and served as the basis for automation, exceeds the scope of this current work. Nevertheless, it serves as an illustration of the enduring nature of the system and its reliance on individuals fingerprint indexers for categorization.

2.1.11. Science-Based Methods of Investigation, Scientific Resources, and Forensic Science Labs

The impetus for the advancement of scientific criminal justice in the United Kingdom occurred during the initial stages of the 1900s and involved a variety of possible frameworks. The Bertillon system's effective organizational standard was undoubtedly attractive, particularly due to its potential for establishing an effective mechanism of record-keeping. However, its complex measuring demands were not as well-received. It should be noted that this system was merely a single component in the larger structure of scientific law enforcement.

The bureaucratic and technoscientific landscape was established as official committees engaged in discussions regarding optimal strategies for criminal identification, recognition, and the implementation of scientific methodologies.

Meanwhile, innovative proposals were put forth by police officers and scientists with respect to the allocation of responsibilities between law enforcement and scientific experts in the creation of scientific tools for detection.(Duvall, 2017)

In 1893, the Home Office of the United Kingdom established a committee with the purpose of evaluating various techniques for identifying repeat offenders and determining the most efficient technique for identification. The Troup Committee, in consideration of the practicality of measurement-taking by law enforcement personnel, recommended an amalgamation of anthropometric measurements and fingerprinting as the preferred techniques in their report subsequent year after careful consideration.

Subsequently, the Belper Committee in 1901 proposed that the criminal identification system ought to rely solely on fingerprinting, a mere few years after this recommendation was made.(Joseph, 2019) In the course of their discussions, the members of the Troup Committee undertook a journey to Paris to observe Bertillon's system, which left a favorable impression on them due to its record-keeping capabilities. Anthropometry's primary advantage was not in establishing identity, but rather in its efficient and straightforward classification system, which was lacking in Galton's fingerprinting system in 1893.(Cole, J. (2004, March).

At present, the classification system for fingerprinting has not yet reached a level of development and efficacy that would warrant its recommendation as the sole method of criminal identification. However, it is anticipated that such a system is on the verge of development.(Duvall, 2017, p. 169) The forensic technique in question lacks the necessary technoscientific infrastructure, specifically a comprehensive database and search technology, to render it instantly feasible. The issue of matching a latent print discovered at a crime scene to a specific suspect persists.

In the ensuing years, the anthropometric system has been subject to growing criticism due to the inconsistent indicators taken by different operators from the

same individual. Additionally, the foreign nature of the instrumentation and metric system utilized in the instruments has contributed to the system's perceived difficulties among British operators. The Belper Committee put forth a recommendation for the utilization of fingerprinting technology, citing its affordability and ease of use. The Committee highlighted the enduring nature of fingerprints over the course of an individual's lifetime, rendering the system applicable to both adolescents and adults.(Cole, J. (2004, March).

The concept of division of labor plays a pivotal role in the implementation of scientific investigation, technological tools, and forensic science. The matter at hand pertained not solely to determining the appropriate course of action, but also to identifying the individuals who would be responsible for executing said actions. Like other technoscientific approaches utilized in the context of crime detection, the establishment of protocols necessitated a collaborative effort, resulting in the emergence of various proposals and operational frameworks. This was particularly evident during the 1930s, a period when scientific methods in the field of British law enforcement were gaining prominence. The aforementioned rules not only established distinct professional roles, but also held considerable significance in terms of epistemology, as they contributed to the formation of specialties and knowledge. In 1901, the Metropolitan Police's Criminal Investigation Department (CID) launched a department dedicated to fingerprint analysis at New Scotland Yard. Subsequently, Henry was appointed as the Assistant Commissioner responsible for overseeing both the CID and the newly created fingerprint department.

Law enforcement officials analyzed and assessed the fingerprint evidence gathered by officers within regional police departments. The utilization of fingerprinting as a law enforcement method, accompanied by a distinct allocation of responsibilities and a suitable centralized database, had proven to be efficacious in England and Wales during the 1930s, coinciding with the growing popularity of other scientific tools. The definition of police technique, as proposed by the Detective Committee,

encompasses different approaches such as photography, latent fingerprint creation procedures, the casting of footprints or coarse tool marks, and suitable techniques for investigating, handling, and packing trace evidence. The committee strongly suggested that all these techniques should be included in the detective training syllabus.(Duvall, 2017, p. 143)

The demarcation between police methodology and forensic science, which represented the distinction between law enforcement activities and the domain of laboratory scientists, had not yet established a definitive boundary. The drive for improved, centrally coordinated law enforcement agencies, coupled with an increasing recognition of the potential for scientific methods to be applied in criminal investigation, were significant factors that propelled the development of a policing approach that was deemed suitably contemporary and scientific. The implementation of both initiatives received support from high-ranking officials in the police and the Home Office. Additionally, there was notable enthusiasm for scientific approaches, particularly among police officers, detectives, certain scholars, and independent scientific experts, although it was not necessarily widespread among the general public.

Cyril Cuthbert exemplified the model of a law enforcement officer who also possessed scientific expertise, a rare combination that allowed him to establish a professional persona founded on the convergence of policing and scientific inquiry.(Wilson, 1959) The term 'science' was broadly defined to consist of various technoscientific advancements including the telegraph, radio, and automobiles. Additionally, it encompassed a more generalized 'scientific approach' that involved meticulous organizing of records and comprehensive exchanges on the identification, dealing with, and packing of trace materials collected from crime scenes.

These aspects would typically fall under the category of police technique if not already classified as such.(Tryhorn, 1935) Furthermore, The British reaction to

criminalistics was the 'scientific aids' movement, which embodied the scientific approach. The provision of "scientific aids" served as a crime scene administration tool for law enforcement officials and investigators, facilitating access to the specialized forensic investigations that were in development and being employed in laboratory settings. The proponents of the 'scientific aids' movement played a significant part in the endeavor to revamp law enforcement by providing scientific backing to set up the detective function on a solid foundation.

The assemblage comprised of individuals with scientific backgrounds, including F. G. Tryhorn (1893-1972), alongside esteemed civil servants, notably Arthur Dixon (1881-1969), who expounded upon the prospective utilization of science in combating criminal activities through publications in the Police Journal and other literary works. This collective effort was instrumental in establishing a scientific foundation for the field of identification.(Else et al.)

2.1.12. Rise of Scientific Policing Cause for a Period of Unease and Apprehension

The issue of placing faith in technology was similarly manifested in concerns frequently articulated regarding the depersonalizing consequences of scientific advancements and the challenges associated with comprehending technological progress. There existed a notable level of interest in the application of scientific principles to the field of criminal investigation in works of fiction. However, such endeavors were confined to the realm of fiction, where the potential ramifications of such pursuits need not be taken into account. Police authorities were equally susceptible to concerns regarding the implications of emerging scientific and technological advancements and their impact on their professional endeavors, much like the general populace. Individuals were in awe of novel technological advancements, yet simultaneously expressed concern regarding their potential drawbacks.(Bantman, 2010)

There is a growing concern regarding the implementation of novel scientific methodologies, particularly with regards to their impact on police training. Prior to the understanding of the potential benefits of scientific techniques, law enforcement officials and investigators exhibited a decreased likelihood of submitting materials to newly established laboratories for examination. In the nascent stages of the Metropolitan Laboratory, Hamish Walls, its inaugural physicist, expressed dissatisfaction regarding the dearth of specimens dispatched to the laboratory by the Metropolitan Police.(H. W., 1972.)

The Report of the Detective Committee (HMSO 1938) proposed a comprehensive training program that encompassed scientific aids. This program presented a possible solution to address the lack of knowledge regarding scientific methods. The reservations regarding the employment of scientific and technological progress in the context of law enforcement ought to be juxtaposed with the near-unmitigated ardor that is evident in forward-thinking publications such as the Police Journal. This periodical, which was established in 1928 and is affiliated with the police service, chronicled numerous advancements in the policing field that were associated with the "scientific aids" movement. The integration of scientific methods in the field of criminal investigation is closely intertwined with organizational considerations. Concerns regarding the implementation of new technologies and resulting changes to organizational structures were closely associated with apprehension towards scientific and technological advancements.

The implementation of scientific methodologies was challenging in the absence of a structured system for maintaining and exchanging criminal records, as well as inadequate means of communication. The insufficient record-keeping practices of police forces globally have resulted in limited ability to exchange information. (Bantman, 2010, p. 35)During a period when records were not centralized and details were not widely shared, it was comparably effortless for criminals to conceal their identities and blend in with the general population.

2.1.13. The Desborough Committee: The Marking of the Initial Stages of the Restructuring of Police Force.

During the onset of World War I, the police force was perceived as a mere assortment of outdated Victorian artefacts. (Thurston, G.Review: A History of Police in England and Wales Medico-Legal Journal) Upon the conclusion of the war, the circumstances remained unchanged. The insufficiency of police personnel, apprehension regarding the physical aptitude of new hires, the emergence of numerous small-scale police forces, and the absence of uniformity in police procedures across England and Wales were among the prevailing issues.(Klein, 2012)

Consequently, the police organization in England and Wales exhibited inadequate preparedness to capitalize on the potential benefits of emerging scientific and technological breakthroughs in crime resolution. This was especially true for advancements that necessitated specialized expertise, devices, dissemination of information, and the capacity to manage extensive centralized databases of criminal data, as required by techniques like fingerprinting and Bertillonage. The period between World War I and World War II was characterized by significant upheaval in the United Kingdom, with a great deal of apprehension surrounding the emergence of political radicalism and any indications of extremist ideologies. In light of this context, the endeavors of the British government to centralize and systematize policing were not solely aimed at modernizing and enhancing the efficiency of policing. Rather, they also served as a mechanism to guarantee that the police force would receive suitable remuneration, working circumstances, and training, thereby enabling them to withstand the sway of extremist political factions.(Klein, 2012, p. 11)

The integration of novel scientific and technological advancements in law enforcement was increasingly perceived as a component of this progression. While this aspect was not overtly apparent, the utilization of scientific methods in

detecting criminal activity as instruments of the governing body in establishing and upholding societal structure thus encompassed a political facet. The utilization of science and technology extended beyond the management of criminal activities, as it was also employed to regulate the conduct of individuals involved in combating crime, within the framework of a disciplinary system influenced by the theories of Foucault.(Sargiacomo, 2009)

The utilization of scientific methodologies as effective tools for enhanced organization and tracking of criminal activities constituted a crucial component of the state's apparatus in countering instances of political radicalism within its own law enforcement personnel. The committee chaired by Lord Desborough served as the foundation for the Police Act of 1919, which established standardized wages and terms at the central level. Additionally, the act established the Police Federation as a replacement for the banned Police Union, which had played a key role in organizing the police strikes.(Reinemann, 1947) The Desborough Committee is commonly recognized as the precursor to the advancement of the UK police force. Despite its perceived lack of efficacy, the committee's efforts were instrumental in establishing a framework for the centralization of organizational and resource-related aspects of policing. This framework would eventually facilitate the integration of scientific advancements into policing practices, in addition to improvements in salaries and conditions of employment.

2.1.14. Formalizing the Detective Profession: Home Office Committees

The establishment of the detective function played a crucial role in firmly connecting laboratory forensic science with the array of contemporary policing and identifying methods, including fingerprinting, as well as other police techniques and advancements in transmission and transportation technology. This argument holds merit in highlighting the significance of the detective role in the integration of forensic science into modern policing practices. The practice of detective work within law enforcement has a lengthy historical background. However, the

emergence of the detective as a distinct expert's role, different from that of the typical police officer, commenced in the latter part of the 1800s in the United Kingdom.(Bredesen, 2013)

During the Victorian and Edwardian periods, detectives were typically chosen from the pool of uniformed policemen, after having served a certain amount of time. The job of detective was highly esteemed and valued intelligence and sound judgement as key attributes for success in the position.(Bredesen, 2013, p. 63) The absence of formal scientific training may have played a role in the apprehensions surrounding the expectations placed upon law enforcement officials and investigators by emerging scientific technologies. Consequently, a discrepancy arose between the elevated standards for the competencies of individuals chosen for the position of detective and the aptitudes possessed by the pool of personnel from which such detectives would undoubtedly be recruited.

The prospect of scientific superiority prevailing over criminal activity remained a far-off aspiration, while law enforcement agencies were sluggish in their efforts to establish themselves as organized and specialized entities. During the post-World War, I era in England and Wales, forensic laboratories were not as prevalent in comparison to their Continental counterparts, such as the highly esteemed Lyon laboratory established by Locard.(Lawrence et al.) Forensic laboratories on the continent were frequently regarded as models of efficient crime-fighting systems, as opposed to the inadequate conditions in England. Prior to the 1930s, forensic practices within English police forces were primarily reliant on the resources available within local laboratories and the effectiveness of detective work as a complement to conventional preventative policing.

In light of the increasing incidence of criminal activities, coupled with the lack of systematic laboratory setup and a disintegrated police system, which was further compounded by the inadequate number of detectives, the efforts of two Home Office committees that were assembled during the 1930s hold significant

pertinence. Two significant committees were established in the mid-1930s and late-1930s, respectively, to investigate criminal activity and detective work in England and Wales. The initial committee was the Advisory Committee on the Scientific Investigation of Crime (HMSO 1936), while the subsequent one was the Departmental Committee on Detective Work for England and Wales (HMSO 1938).

The Scientific Advisory Committee acknowledged the need for the Metropolitan Laboratory to establish strong connections with law enforcement agencies but did not provide specific recommendations on how to achieve this objective. As per the findings presented by the Scientific Advisory Committee, the establishment of laboratories to apply scientific principles in solving crimes is undoubtedly beneficial. However, it is imperative to acknowledge that this approach only addresses a fraction of the broader issue. To achieve a comprehensive solution, it was crucial to extend beyond the limited scope of police necessities.(Duvall, 2017, p. 140)

While other nations possessed medico-legal establishments and prominent chairs of forensic medicine at universities such as Edinburgh and Glasgow, London lacked a comparable institution. It is unlikely that the Metropolitan Laboratory would have the capacity to manage the full spectrum of industrial illness instances post-mortem examinations, and scholarly advancements in the field of forensic medicine. The omission of any subsequent reference to the potential evolution of the relationship between science and law enforcement agencies in the context of crime detection was noted. The report indicated a lack of specialized forensic organizational expertise in various areas, despite its primary emphasis on the medical aspect.

2.2. The Detective Committee

The establishment of the Detective Committee was aimed at investigating the uncovering of criminal activities in England and Wales, with a particular focus on examining the organizational aspects of law enforcement. The committee's efforts were categorized into four interrelated areas, namely the recruitment and education

of investigators, criminal documentation, communication, and scientific tools employed in the identification of criminal activities. The aforementioned list holds great significance as it establishes a connection between scientific analysis and the education of investigators, as well as other facets of technological innovation and documentation handling in scientific investigation.

This encompasses the entire range of technoscience and information technologies. The inclusion of such links was beyond the scope of the Scientific Advisory Committee's mandate. The Home Office played a crucial role in the centralization of police organization and training, as well as in the professionalization and expansion of the detective's assignment. Additionally, the Home Office was instrumental in the establishment of new laboratories, all of which made a noteworthy impact on the development of forensic science. It is not entirely inaccurate to assert that the Home Office played a significant role in the development of forensic science.

The Home Office facilitated the popularization of the term "forensic science" by establishing a forensic science laboratory network after the efforts of the Detective Committee. This development occurred during the 1930s. Several primary and secondary sources attest to the significant level of investment made towards establishing forensic science laboratories during the 1930s. This was done in conjunction with the introduction of forensic science examinations in policing during the same period. Additionally, the work of autonomous scientific experts and public analysts in food and product contamination continued to be of importance during this time.(Ward, 1993)

The Report of the Detective Committee establishes a definitive correlation between the function of detectives and the application of scientific methods, specifically forensic science, in the identification of criminal activity. The implementation of this vital association is manifested in the structure of detective training programs. The statement not only promotes the importance of scientific tools, but also

emphasizes the inclusion of forensic science in scientific detection. The report issued by the Detective Committee unequivocally announced the emergence of the scientific detective.

2.2.1. Sub-committee D: Implementation of Scientific Methods in the Examination of Criminal Activity.

According to the fifth volume of the report, which falls under the purview of sub-committee D, several measures were being undertaken to address the insufficiency of scientific material in detective training programs.(Duvall, 2017, p. 144) The committee was presented with testimony from the forensic pathologist Spilsbury and Home Office Analyst Roche Lynch. Despite their medical training, they possessed extensive expertise in forensic investigations and conducted chemical examinations. The Detective Committee conducted a comprehensive examination of investigative efforts both domestically within the United Kingdom and internationally. Several law enforcement agencies in England and Wales had established their own laboratories or utilized the resources of close by research centers and training facilities.

Upon the completion of the Detective Committee's report, the Metropolitan Laboratory was established in conjunction with the Metropolitan Police College located in Hendon. Additionally, local testing facilities situated in Nottingham, Cardiff, and Birmingham had already commenced their operations. The Home Office had disseminated a comprehensive brochure on scientific aids to all relevant personnel, while a set of Forensic Science circulars had been introduced.(Duvall, 2017, p. 144) According to the committee's assertion, approximately 4% of incriminating offences would necessitate scientific examination of evidence, resulting in over 10,000 crimes annually. There existed a significant potential for additional advancement. The committee acknowledged the existence of three distinct tiers of testing, namely regularity, expert, and exploration. In response to the proposals for a medico-legal institute, the Detective Committee put forth a

suggestion for a Forensic Science Centre that would provide comprehensive assistance to the entire service. This facility would ideally include an investigatory laboratory, library, gallery of specimens, and administrative resources to facilitate coordination among the network of forensic science laboratories. Additionally, it would serve as a hub for propagating knowledge and for fostering collaboration with educational institutions. The proper management, packaging, and transportation of materials to the laboratory were deemed to be of utmost significance. The report suggests that detectives should possess a basic understanding of laboratory analyses, despite not being responsible for conducting them.

This understanding would enable them to comprehend the potential of laboratory work in different areas and enhance their overall comprehension of the topic. As a result, it is recommended that detectives receive training that includes demonstrations of several approaches. Despite this, the report did not suggest that detectives possessing scientific expertise should engage in any preliminary handling of the evidence. Rather, it emphasized the distinction between police methodology and the actual analysis of trace proof, thereby bolstering a clear separation of professional responsibilities. The first category was traditionally regarded as a task assigned to law enforcement officials, while the second was unquestionably within the domain of a laboratory specialist.(Ward, 1993, p. 146) A developing trend in the allocation of responsibilities between scientists and detectives is the establishment of a suitable split of labor.

2.2.2. The Metropolitan Police Laboratory: A Rocky Start

The challenges of defining professional responsibilities and establishing a distinct identity for the emerging field of forensic science were exemplified by the early struggles of the forensic science laboratory affiliated with the Metropolitan Police. This was due, in part, to the need to navigate the existing domains of forensic pathologists and autonomous forensic scientists, as well as the expectations and

demands of the police service. The reason for its downfall can be attributed to a confluence of factors, including suboptimal leadership from its initial director who possessed expertise in pathology rather than the natural sciences. The field of sciences has been observed to adopt an anti-scientific strategy regarding certain aspects of its work, which has resulted in discord towards its connection with the Police College it is affiliated with, especially among the police community.

2.2.3. Local Crime Scene Investigation Facilities

The Metropolitan Police Laboratory served as a pioneering institution for the emerging field of forensic science, thereby rendering its triumphs and shortcomings conspicuously apparent. The performance of the regional laboratories was comparatively superior. Nevertheless, it would be inaccurate to imply that the establishment of these laboratories was devoid of challenges to surmount. This is primarily because it involved the implementation of a governmental framework in a domain that had hitherto been characterized by a laissez-faire approach.(Ward & Mphil, 1993, p. 151)

During the 1930s, the Nottingham Laboratory functioned as a police laboratory and was greatly facilitated in its accomplishments by the fervor of Chief Constable Popkess, who exhibited a strong inclination towards the utilization of scientific methods in the realm of detecting crimes. The Nottingham Laboratory underwent a transitional phase beginning in 1936, ultimately resulting in its regionalization and establishment as the inaugural Home Office Regional Forensic Science Laboratory in 1938.(Ward & Mphil, 1993, p. 152)

Subsequent to this, regional research facilities located in Cardiff, Bristol, Birmingham, and Preston were scheduled to be established.(Ward & Mphil, 1993, p. 153) The inauguration of forensic science laboratories was documented in local as well as national newspapers. The perspectives conveyed in these reports were predominantly positive regarding the contribution of forensic science to combat criminal activities. Unquestionably, the inauguration of official laboratories

provided great possibilities for public relations, as regional and national newspapers could disseminate the optimistic communication of senior civil servants, local government officials, and chief constables, emphasizing the significance of the police-scientist partnership in resolving present offences and preventing future ones.

The official inauguration of the Northwestern Laboratory in Preston in 1939 received coverage by the Manchester Guardian. The article highlighted the laboratory's extensive range of tools and amenities, which had expanded significantly from its humble beginnings in a two-room terraced house. Additionally, the inaugural speech delivered by Dixon was also covered in the report.(Ward & Mphil, 1993, p. 154)

The legal disputes among scientists may have had negative implications for the epistemological validity of forensic science, a field that is still in its early stages. Additionally, it may have discouraged non-compliant law enforcement agencies from utilizing their local laboratories if they believed that their proof would be challenged by a specialist from an external laboratory, whether independent or under the supervision of the Home Office.(Ward & Mphil, 1993, p. 157) Despite the presence of several autonomous expert witnesses, the newly established state laboratories were essentially assuming authority over scientific matters in support of the criminal prosecution.

2.2.4. The Scientific Aids Campaign

Despite variations in methodology among regional laboratories and chief constables, the 1930s witnessed a significant drive towards the segregation of duties among police officers and detectives within the Metropolitan and regional police forces. The professionalization of the detective function was accompanied by a corresponding debate regarding the appropriate operations for police officers, detectives, and scientific laboratories in the context of utilizing scientific methods for detecting crimes.

The aforementioned endeavors encompassed the creation of a compendium of protocols for law enforcement personnel to execute at the site of a criminal incident, as well as the advancement of the field of forensic science. The mentioned phenomenon can be classified as the 'scientific aids' movement, which is the British counterpart of criminalistics. The campaign in question had a primary focus on policing, but it also involved the participation of scientists who played a key role in establishing a chain of forensic science laboratories and designing relevant instructional programs. Notable figures in this movement included C.T.

Symons and F.G. Tryhorn, who emerged as prominent scientists and eventually assumed leadership positions, with Tryhorn serving as Director of the Harrogate Laboratory and subsequently as Home Office Forensic Science Adviser.(Ward & Mphil, 1993, p. 157)

The tools and instruments utilized in scientific research were not considered as scientific endeavors in and of themselves. It would be more accurate to classify them as a component of criminalistics or forensic technoscience, given that the narrative encompasses the integration of administrative and technical infrastructure. The promotion of scientific aids was aimed at facilitating the comprehension and demarcation of the potential applications of science in crime detection, as required by police officers and detectives. The incorporation of administrative objectivity was deemed necessary to ensure the proper execution of processes involved in the advancement of forensic science.

The utilization of DNA profiling in forensic contexts has attained a significant degree of epistemic assurance due to the fact that the procedures involved have been acknowledged by criminal justice entities as being administratively impartial.(C, 2013.) The concept of DNA evidence's "administrative objectivity" is based on the adherence to explicit and documented bureaucratic procedures, the use of reliable recording equipment, the implementation of established protocols, and

the arrangement of physical spaces in a manner that facilitates accurate reporting. (C, 2013, p. 60)

During the 1930s, fingerprinting had attained administrative closure, which contributed to its relegation to the domain of police methodology. Similar to the implementation of fingerprinting in the early 1900s and contemporary forensic DNA profiling, the forensic science of the 1930s necessitated the establishment of a consensus on administrative objectivity. The "scientific aids" methodology played a significant role in attaining this objective. The incorporation of a scientific conduct to identification in response to an increase in assets offences, along with the professionalization of the detective duty, were significant factors that contributed to the emergence of forensic science laboratories and scientific aids in policing. Arthur Dixon certainly played an essential role in the field, and the efforts of the Detective Committee, specifically Sub-committee D, were instrumental in advancing vital reforms. This included outlining the training necessities for detectives, incorporating scientific tools into detection practices, and establishing a network of forensic science laboratories. Following the establishment of the Metropolitan Police Laboratory, which initially faced challenges, several regional forensic science laboratories were subsequently established. Despite an unclear inception, forensic science laboratories were operational in England and Wales by the onset of war, and a discipline known as forensic science, which was conducted by forensic scientists, had been established.

3. Development of Forensic Science in United States of America.

3.1. Humble Inception Forensic Science in Latin America

The origins of forensic investigation in the United States can be traced back to the inception of forensic pathology. In essence, forensic science can be characterized as a more expansive discipline encompassing forensic pathology. Forensic pathology involves the utilization of forensic science and pathology in the examination and analysis of deceased individuals for investigative

purposes.(Prahlow & Byard, 2012) The first autopsy conducted in North America took place in Santo Domingo, presently known as the Dominican Republic, in the year 1533. This postmortem examination involved the scrutiny of conjoined twins.

The primary objective was not to ascertain the underlying factor leading to the cessation of vital functions. Numerous trailblazers in the field of medicine emphasized the significance of the postmortem examination in the realm of medical pedagogy throughout the 20th century. One notable individual who exemplified pioneering efforts in the field was Sir William Osler (1849–1919), who demonstrated a strong passion for the practice of autopsies. Following the culmination of his academic pursuits in Canada and Europe, Osler proceeded to engage in pedagogy at McGill University while concurrently fulfilling professional responsibilities at the Montreal General Hospital. In 1892, he authored the publication titled "The Principles and Practise of Medicine," drawing upon their extensive experience in conducting autopsies at the hospital.(Tilstone et al., 2006)

3.2. Having Access to Forensic Tools by Medical Students

In the year 1870, the accessibility of microscopes to medical students was facilitated by technological progress. The establishment of the inaugural comprehensive crime laboratory occurred in Los Angeles in 1923, drawing inspiration from the pioneering work of Locard's laboratory. In order to enhance the accessibility of forensic science, the Federal Bureau of Investigation established a laboratory in 1932.

The advent of these activities marked a significant milestone in the United States, as it facilitated the widespread accessibility of forensic sciences. The establishment of forensic laboratories at both local and state levels has emerged as a widely recognized model. Over time, forensic laboratories have incorporated various advanced investigative strategies and devices from the fields of medicine and industry in order to enhance their practicality.

The forensic specialist typically assumed the role of team leader within the forensic team and frequently served as the sole physician employed on a full-time basis. Part-time consultants in the field of forensics also contributed significantly to the forensic team.(Prahlow & Byard, 2012, p. 91)

3.3. Creation of Forensic Examination System

The establishment of the forensic examination system in the United States can be traced back to the influence of the English coroner system. The establishment of an English coroner's office can be traced back to the year 1925, although its origins can be found in the Articles of Eyre from 1194. Coroners did not possess medical qualifications.

The responsibilities of the coroner encompass the examination of deaths resulting from acts of violence, deaths that occur suddenly or unexpectedly, deaths that arouse suspicion, and deaths that occur in the absence of a physician. The training of coroners varied from a complete absence of training to a duration of one to two weeks. Based on the fundamental training received, the coroner utilized their knowledge and expertise to determine the cause and manner of death. These actions could potentially result in substantial criminal and civil ramifications. The coroner system in England did not achieve nationwide implementation until the latter half of the 19th century.(Prahlow & Byard, 2012, p. 91)

The year 1877 witnessed the implementation of a legislative measure mandating the conduction of an inquiry in cases where the coroner possessed sufficient evidence to believe death resulting from violence or unnatural causes, or when the reason of death remained undetermined. Consequently, the coroner system established a comprehensive investigative agency that addressed all fatalities. The documentation of medical-legal matters in the colonies commenced in 1635, facilitated by the introduction of the coroner system by the early colonists. During the 17th century, a distinct field of study known as forensic medicine started to develop.

In the 19th century, the field of pathology in the United States was significantly shaped by the impact of Virchow and the German School of Pathology. The initial medico-legal utilization of an autopsy took place in Maryland, United States, in the year 1665. The requirement for a physician's presence in instances of violent fatalities became imperative following the implementation of the "Code of Public General Laws" in Maryland in 1860. In 1868, the Maryland legislative body designated and authorized a physician to serve as the sole coroner in Baltimore. In 1890, a municipal regulation was enacted, granting the Board of Health the authority to designate two medical practitioners in the city of Baltimore.

The individuals in question were tasked with carrying out all autopsies as asked by either the coroner or the state's attorney of Baltimore City.(Guerrini, 1995) The introduction of the first medical examiner system in Massachusetts occurred in 1877. As a result of the conflicts encircling the coroner's system, the Commonwealth made the decision to implement a statewide structure that mandated the replacement of the coroner with a medical examiner, who is a qualified physician. To ensure effective execution, the state was partitioned into distinct sectors, with each sector being assigned a physician medical examiner responsible for determining the cause and manner of death. The amendment to the Massachusetts law in 1945 granted the medical examiner discretionary authority to conduct autopsies.(Greenfield et al., 2002) The current medical examiner system in operation today was established in New York City. The coroner's office in New York City was abolished in the year 1915. The establishment of a medical examiner system involved the appointment of a chief medical examiner, who served as a chosen pathologist. It is worth noting that forensic pathology was not yet recognized as a distinct field at that time, but rather emerged as a subspecialty in 1959. One of the primary functions of the medical examiner system is to conduct investigations into deaths that are a consequence of criminal violence, accidents, and suicide.

The medical examiner was granted the jurisdiction to determine the necessity of an autopsy and was provided with a dedicated laboratory facility for conducting such procedures. As a result of these advancements, certain scholars perceive this establishment as the initial legitimate medical examiner's office.(Prahlow & Byard, 2012, p. 92) Dr Charles Norris, the founding chief medical examiner appointed for New York City in 1918, played a pivotal role in advancing the field of forensic medicine through his notable inputs to research and the expansion of service provisions. The expansion of the medical examiner's office in New York City occurred during the tenure of Dr. Milton Helpern, who served as the third chief medical examiner.

Currently, the majority of medical examiner systems in the United States have embraced the New York concept. Conversely, certain more recent systems demand that the chief medical examiner possess expertise in forensic pathology. The establishment of the first statewide medical examiner's system took place in Maryland in 1939. The recruitment of the chief medical examiner was conducted by a commission specifically designated for this purpose. This commission consisted of professors of pathology from two medical schools, the executive officer of the State and Baltimore City Health Departments, and the superintendent of the State Police.(Prahlow & Byard, 2012, p. 92)

The establishment of the initial professional police forces occurred in various states within the United States. Specifically, Boston witnessed the formation of its professional police force in 1837, followed by New York in 1844, and Philadelphia in 1854. By the 1870s, the majority of prominent cities in the United States had established municipal police departments.

3.4. The Pinkerton National Detective Agency

Similar to England, the practice of conducting criminal investigations by public law enforcement was perceived as politically detrimental. The policy primarily benefited individuals with the financial means to afford it. Nevertheless, the rapid

urbanization led to the disintegration of social cohesion in small communities as a consequence of the prevalence of violence, crime, and related behaviors. The proliferation of instances of mob violence between Protestants and Catholics, the increased responsibilities placed upon immigrants and native Americans by the police force, and the confrontations between abolitionists and pro-slavery factions can be identified as some of the most significant catalysts.

The Pinkerton National Detective Agency, founded by Scottish immigrant Allan Pinkerton in 1850, holds the distinction of being the very first detective organization in the United States. The Federal Bureau of Investigation (FBI) later embraced the organizational structure of this agency. The Pinkerton Agency was engaged by communities to address cases that local law enforcement agencies were unable to investigate due to their perceived lack of competence. The Pinkerton field of criminal investigation introduced numerous advancements in the realm of identifying crimes. Similar to Europe, the initial pioneers of forensic anthropology in the United States were individuals with expertise in anatomy and medicine who became involved in the practical application of their field through casework.(Prahlow & Byard, 2012, p. 93)

One notable individual who exemplifies this occurrence is Jeffries Wyman (1814–1874). Wyman, a renowned academic in the field of Anatomy and the first curator of the Peabody Museum of American Archaeology and Ethnology in 1866, conducted significant research on human remains obtained during a remarkable murder investigation at Harvard. The unfortunate incident involving the loss of Dr. George Parkman's life was attributed to the actions of John W. Webster, a faculty member at Harvard University. The motive behind this tragic event was reportedly related to loan repayment, as Dr. Parkman was not only a prominent physician but also a generous benefactor to the university who operated a loan business. Following the demise of Parkman, Webster proceeded to confiscate certain anatomical components, subsequently subjecting them to incineration within the confines of his laboratory furnace. Wyman was summoned to ascertain the identity

of the incinerated remains and establish their congruity with the anatomical components that had been extracted from the body.(Prahlow & Byard, 2012, p. 93)

The field of forensic anthropology was pioneered by Thomas Dwight in the United States. Dwight authored a series of articles and essays focused on the recognition of human skeletal remains, earning him the esteemed designation of "Father of American Forensic Anthropology." Dwight holds the distinction of being the first American anatomist to engage in research pertaining to the field of forensic anthropology. George A. Dorsey (1868–1931) was a pioneering figure in the field of forensic anthropology, being the first expert with a background in anthropology to actively engage in forensic investigations. Dorsey conducted a study on human cadavers that were retrieved through archaeological means.

He made a significant contribution to a forensic case of considerable public interest. Upon commencing employment at the Field Columbian Museum in Chicago in 1896, Dorsey actively participated in the investigation of a Chicago-based banger manufacturer. The individual in question was charged of murdering his wife and subsequently attempting to conceal the evidence by cooking her corpse in a large container at the factory.(D. H. Ubelaker, 2006) Only a small number of fragments were retrieved. Dorsey deemed it imperative to locate the absent cadaver of the mature female individual. The evidence presented by him in question received significant criticism from other experts in the field. Following this incident, Dorsey refrained from making any additional contributions to the field of forensic anthropology.

The establishment of the physical anthropology division within the American Academy of Forensic Sciences (AAFS) in 1972 marked a significant milestone in the evolution of forensic anthropology. Within a distinguished institution specializing in the field of forensic science, Ellis R. Kerley (1924-1998) and a group of 14 coworkers collectively made the decision to initiate the introductory course

for the newly established division of physical anthropology.(D. U.-J. of F. Sciences & 2001.)

Following this launch, forensic anthropologists could convene and present their findings and casework during a yearly gathering. The Journal of Forensic Sciences was established by the Association for the purpose of disseminating research reports. As a result, there was a significant increase in the number of individuals joining the section, with membership surpassing 260 members by the year 2004.

4. Development of Forensic Science in India

4.1. Introduction

Beginning in the 18th century, the increasing specialization of scientific disciplines led to the emergence of novel perspectives on scientific concepts and principles, thereby expediting advancements in both theoretical frameworks and methodological approaches. In India, particularly from the late 1800s onward, various breakthroughs in science have significantly impacted scientific paradigms and their practical implementation for the betterment of humanity, eventually resulting in the material advancement of society. The development of forensic science in India is a complex and extensive narrative that has yielded diverse outcomes across various civilizations.(Basu, 2021)

Following the conclusion of the 1857 rebellion, British India experienced a drive to overhaul the entire penal system and introduce a novel Indian Penal Code,1860 thereby showcasing colonial dominance in a more compelling fashion. During the 19th century, significant changes were made to three criminal codes, namely the Indian Penal Code,1872 Criminal Procedure Code,1973 and the New Police Regulation. The initial two statutes bestowed a novel configuration upon the colonial governance.

The preceding historical context of colonial dominance reveals the notable significance of the final instance, wherein the police force successfully established

a successful system and controlled heinous crimes. This achievement stands in stark contrast to the previous experiences of colonial rulers, who experienced the inadequacy of the police force in fulfilling the intended goals of the Company Raj. The institutionalization of criminal investigations emerged as a novel approach to colonialism in this undertaking, with the founding of various forensic institutions across different Presidencies occurring at this juncture.(Basu, 2021, p. 14)

In this context, the implementation of various legal statutes held significant significance. This legislation not only facilitated a novel perspective in the realm of accurate identification of criminals for scientific assurance but also brought about a substantial transformation in the notion of crime. To establish greater authority over their colonies and to solidify their permanent hold on the Crown, imperial rulers implemented changes to the law and regulations, including the introduction of forensic science as a means of asserting scientific dominance in the Indian subcontinent.

Several variables served as sources of encouragement for the creation of distinct forensic science establishments in colonial Calcutta in relation to India. Various social changes and anti-British motion were observed. The scientific supremacy observed in the sociopolitical context can be attributed to an ideological pursuit of colonialism, aimed at reinforcing the dominance of Western scientific principles in the realm of criminal recognition within the framework of colonial rule.(Basu, 2021, p. 15)

4.2. Quest for Scientific Knowledge and Advancing Civilization

The discipline of forensic science is a specialized and impressive field with a rich historical background that spans many years. The philosophical principles of this exceptional discipline align with the sastriya tradition expounded in various ancient Indian religious scriptures, which aim to comprehend truth in its entirety. Historically, criminal investigations heavily relied on testimonies from eyewitnesses to resolve cases. Frequently, acts that were violent were attributed to

chance occurrences, instances of intoxication, purportedly supernatural practices such as witchcraft, or perceived divine punishment. Similarly, ailments were commonly explained as resulting from an inequity in the bodily fluids known as "humors".

Over time, humanity has progressed in its acquisition of knowledge, which has correspondingly resulted in advancements in the realm of justice. The dissemination of crime-related data became increasingly widespread as public interest in the intricacies of criminal activity.

4.3. The Inception of Criminal Investigation in India from A Historical Perspective.

4.3.1. Ancient India

The utilization of science and technology for the purpose of identifying criminal activity, examination, and justice administration is a well-established practice in India. Despite the lack of contemporary forensic science knowledge among our predecessors, it appears that scientific methodologies were utilized to some extent in the examination of criminal activity. The conventional framework of state judicial administration can be tracked back to the pre-mauryan era (326-185 BC), serving as a bridge that links two significant periods of administration, namely the Dharma Sutra and Manu's Code.

Megasthenes's Indica, Pillar Edict IV of Ashoka, the legal and judicial systems of various historical periods such as the pre-Gupta era, the Kushanas, the Guptas, king Harshavardhana, and the Chalukyas provide abundant source on the laws and societal safeguards against malevolent acts, as well as the corresponding punishments for criminal offences. Throughout each dynasty, the governing class established legal and administrative systems, as well as a criminal justice system, with the aim of preserving societal order and tranquilly.(Rama, J.M. (2010). The Hindu legal system was wholly integrated into dharma, as expounded in the Vedas, Puranas, and Smritis.

Based on various indications present on a human body, it is possible to infer the way the individual was killed. The Prakarana "Asumrtakpariksa" within Kautiliya's Arthasastra delves into various forms of slaughtering and their corresponding inquiries. These include smothering, hanging, impalement, immersion, intoxication, and being slain by a stick. A special focus has been given on the topic of mortality, including but not limited to instances of abrupt death, asphyxiation, hanging, drowning, physical assault, as well as fatalities resulting from poisoning and homicide.

The law of evidence was incorporated in cases that were both civil and criminal in nature, as well as the procedure for investigating crimes and the approach to punishment. Additionally, a code of conduct for judges and the monarch was established. The police system, dating back to the pre-Mauryan period, demonstrated a high level of efficacy in deterring breaches of administrative and criminal law. The administration of penalties, also known as Dandaniti, constituted a significant aspect of the legal structure in ancient India, particularly regarding the various categories of criminal offences. Due to the impact of the criminal justice system, the scrutiny of witnesses and the act of committing perjury have been regarded with great importance.

Forensic toxicology, a field concerned with the medical and legal implications of chemical-induced harm to humans, is referenced in historical literature.(Payne-James & Byard, 2015) The antiquated Indian scriptures make mention of the act of poisoning kings, as well as the activities of individuals who were professional poisoners, such as Vish Kanya, Vridha Vagbhata.(C, p. 29) Additionally, these scriptures allude to the occurrence of systematic poisoning during both pre-historic and historic periods. The Shastras provide a comprehensive account of the signs and remedies for poisons in Kalpasthana, Chikitsasthana, and Uttarasthana. Toxicology's roots in India can be traced back to the Vedic era. The Atharva Veda contains the initial reference to poisons.(C, 2013.)

The text provides various remedies for a range of diseases, including those caused by poisoning. The Agnivesa Caraka Samhita is a significant contribution to this area of study, as it encompasses information regarding indications, manifestations, and remedies for frequently encountered toxic substances. The Susruta Samhita, a significant contribution to Indian medicine, included a section dedicated to the study of poisons. In ancient India, Susruta documented various methods of poisoning.

The individual recounted the various methods by which toxins were incorporated into substances such as food, beverages, honey, medicinal products, bathing water, oils for anointing, fragrances, pigments for eyelashes, and snuff. Additionally, the poisons were dispersed over items such as clothing, bedding, furniture, footwear, adornments, horse saddles, and so forth. The act of secretly contaminating wells and other sources of water for consumption as a means of eliminating adversaries was explained.(C, 2013.) Agada tantra, a subfield of Ayurveda, primarily focuses on the study of toxins. The text outlines various methods for eliminating toxins from the body. A diverse array of toxic substances was cited, originating from either animal or plant kingdoms.

The term also encompasses hazardous materials obtained from minerals such as arsenic, as well as synthetic poisons. In accordance with a legend from the Maurya period, it is believed that Chanakya, the esteemed prime minister of Chandragupta Maurya, implemented a practice of gradually introducing minute quantities of poison into Chandragupta's meals, with the intention of acclimatizing his system to its effects. The primary objective was to safeguard the emperor from potential poisoning attempts orchestrated by adversaries. On a particular occasion, it was observed that upon partaking in a meal with the emperor, the pregnant queen Durdha met her demise.

To ensure the safety of the infant, Chanakya performed a surgical procedure by extracting the baby from the queen. However, inadvertently, a minute quantity of

toxic substance had come into contact with the infant's cranium. He was given the name Bindusara because of the presence of a toxic substance on his forehead.(C. 2013, p. 30)

4.3.2. Medieval Period

Nevertheless, the Hindu regime experienced a decline in power during the latter part of the 11th century. The Indian governance underwent a gradual process of being taken over by Mughals. The Muslim rulers, who held positions of authority, placed significant emphasis on the administration of criminal justice. In their efforts to enhance the judicial machinery, they implemented numerous reforms.(E. B. 1885.) The Muslim emperors primarily adhered to Islamic law, also known as Shariah.

Historically, criminal law was regarded as a subdivision of private law as opposed to public law. The primary sources of Islamic law consist of the Quran, Sunnah, and hadiths. During the Muslim era, as stated by Hanafi Law, evidence was classified into three distinct categories: Tawatur, which refers to evidence that is fully corroborated; Ehad, which pertains to the testimony of a single individual; and Iqrar, which encompasses admissions, including confessions. The legal requirements pertaining to the presentation of evidence in order to establish the commission of the offence were characterized by a significant level of technicality. However, despite the presence of a well-structured judicial system, Muslim criminal law exhibited certain shortcomings, particularly in relation to murder, homicide, discretionary punishment based on ambiguous evidence, and other related matters.(Prahlow & Byard, 2012, p. 31)

4.3.3. Colonial India

India emerged as a sovereign entity during the colonial period under British rule, which commenced in the early 17th century with their arrival as traders. Over time, the British eventually expanded their territorial control throughout the continent of

India, primarily assuming administrative authority. The Company implemented an array of rules aimed at reforming the Hindu and Muslim criminal law, which it perceived as illogical and arbitrary. These laws sought to modify or broaden the existing definitions of certain crimes. New legislation was implemented to address newly identified crimes, resulting in significant modifications to sanctions with the aim of enhancing their rationality and realism.

During a period of significant development in the administrative system, a new era of the judiciary system emerged. As part of this transformation, forensic science, a prominent scientific discipline, was incorporated into the criminal justice system. This integration aimed to enhance the pursuit of truth by employing scientific methodologies. This marked the scientific inception of authentic methods for detecting criminals in British India.

4.3.4. The Growth of Forensic Science Organizations in Imperial India

The discipline of forensic sciences underwent significant development towards the close of the 18th century. The commencement of modern chemistry can be traced back to the conclusion of the 18th century. This development paved the path for the emergence of the field of toxicology. One of the most prominent figures in the field of toxicology throughout history is widely regarded to be M. J. B. Orfila (1787–1853). During the period from 1840 to 1947, the British Indian state established various institutions with the purpose of scientifically detecting and investigating criminal activities. The newly appointed specialists in India, who possess expertise in toxicology, blood stain analysis, examination of handwriting, and exploding substances were expected to effectively address the issue of perjury and forgery committed by individuals of questionable credibility. Their primary objective was to extract impartial and scientifically verifiable truth, thereby serving the cause of justice with a neutral perspective.

4.4. Formalizing the Process of Identifying Criminals by the British Indian Government.

From the late 18th century to the early 19th century, the occurrence of death by poison became prevalent, presenting an unusual situation for the law enforcement departments of colonial authorities. The identification and isolation of various types of toxic substances, which have resulted in multiple fatalities, posed a challenging endeavor. To address this challenge, the British authorities envisioned the establishment of a novel enterprise. Consequently, the British India region saw the inception of the chemical examiner's laboratories, which aimed to provide autonomous scientific support to the criminal justice administrative framework.

The inaugural establishment of the chemical examiner's laboratory in India occurred in Madras on October 30, 1849. The laboratory of the chemical examiner provided services to the judiciary in the pursuit of prosecuting criminal activities. The initial individual to hold the position of chemical examiner in Madras was P. Thomas Ray, who also happened to be a surgeon. Following the recognition of the significance of this endeavor, analogous research facilities were founded in Calcutta in 1853, and subsequently in Agra in 1864 and Bombay in 1870. Each of these laboratories established and retained a network throughout British India.

All the testing facilities belonging to the chemical examiner were furnished with the necessary resources to perform toxicological analyses on a wide range of specimens, including human and animal organs, blood marks, stool, soil, food, stomach contents, apparel, sleeping material, firearms, narcotics different excisable substances, and appliances for cooking. The scientific reports proved to be highly influential within the legal system, while also contributing to the emergence of a novel discourse surrounding various topics such as intoxication, serology, microbiology, drug contamination, chemical warfare, and weapons of mass destruction within the British Empire.(Prahlow & Byard, 2012, p. 136)

4.5. Anthropometric

The struggle of criminal verification persisted for the British governance in India, starting from the mid-19th century and continuing even after the creation of chemical examiner's laboratories in various regions of the country. Various forms of criminal activities, such as dacoity, burglary, theft, and even homicide, have become prevalent occurrences that posed significant challenges to law enforcement authorities. Despite the advent of photography in 1826, the Criminal Investigation Department (CID) frequently encountered a prevalent challenge in accurately identifying perpetrators due to their tendency to alter their physical looks following the commission of an offence. In many instances, the CID police were confronted with individuals who posed a significant threat due to their accustomed criminal behavior.

However, these individuals were often categorized as first-time offenders as they concealed their true identities and the criminal histories of their ancestors. Given the circumstances, the Inspector General became aware of the need to develop methods for recognizing the most perilous offenders. Consequently, this resulted to the implementation of the "anthropometric system" as a means of accurately discovering criminals. In 1878, India, like numerous other nations, embraced the anthropometric system developed by Alphonse Bertillon. Alphonse Bertillon initially commenced his professional journey as a clerk within the Paris Police.

In 1879, he, deeply disturbed by the inadequate state of record-keeping and the absence of dependable criminal identification systems, endeavored to devise a solution to address these pressing issues. Bertillon devised a method consisting of anthropometric measurements of immutable body parts, employing specifically developed calipers, gauges, and rulers. The prisoners were subjected to a series of 11 meticulous evaluations, including height, head length, head breadth, arm span, sitting height, length of the left middle finger, length of the left little finger, length of the left foot, length of the right ear, and width of the cheek. The measurements were systematically arranged into a sophisticated indexing system with the assistance of clerks who received specialized training. In instances where

individuals could not be readily identified, clerks would navigate the filing system by systematically exploring increasingly specific subdivisions of measurements. This process would culminate in the creation of "anthropometric cards" containing information on individuals who met the specified measurements.(Prahlow & Byard, 2012, p. 137)

Due to the relatively low probability of two individuals sharing precisely identical 11 measurements, a method of deduction utilizing facial description could be employed on the most minimal subset of individuals. Initially, Bertillon adamantly advocated for the inclusion of exclusively accurate and elaborate characterizations of criminals on these descriptive cards, employing standardized terminology that he referred to as a "portrait parle." Bertillon expressed skepticism towards the perceived objectivity of photographs and aimed to substitute the mug shot with standardized language as the means of police interactions and investigation.

He promptly recognized the impracticability of his undertaking, nevertheless, and hesitantly opted to incorporate mug shots as a supplementary component to his system.(Prahlow & Byard, 2012) He strongly advocated for the adoption of a standardized and scientifically rigorous approach to capturing mug shots by law enforcement officials. This method aligned with the meticulous nature of the individual's overall system and demonstrated a commitment to maintaining a professional and impartial perspective within the police force. Bertillon hypothesized that ears could potentially serve as a distinctive identification feature akin to fingerprints.

Consequently, he advocated for the inclusion of a profile view in addition to the standard frontal mug shot. During the late 19th century in Europe, the system developed by Bertillon enjoyed greater popularity compared to fingerprinting. However, the complexity and unreliability of the system made it impractical to sustain. In the end, fingerprinting became the prevailing method of identification worldwide. However, the Bengal Police adjusted the number of body part

evaluations based on specific needs and circumstances. Instead of utilizing 11 measurements, the researchers opted to employ a reduced set of six measurements, namely the length and width of the head, the length of the left middle finger, the length of the left forearm, the length of the left foot, and the overall height. Additionally, they incorporated the impression of the ball of the left thumb and a more distinct permanent marker, which had not been included in the previous French system. In a formal correspondence, specifically letter no. 263, dated May 10, 1892, the Secretary to the Government of India issued official instructions to H. J. S. Cotton, the Chief Secretary of Bengal along with other provinces, regarding the implementation of the Bertillon System of Anthropometry. This system was to be utilized for the purpose of identifying recidivist and perpetrators. In 1892, an Anthropometric Bureau was established at Writer's Building in Calcutta for the purpose of maintaining anthropometric records of habitual criminals and offenders.(Prahlow & Byard, 2012, p. 138)

4.6. Fingerprinting and Identification

Sir William Herschel was a pioneering proponent for the utilization of fingerprinting as a means of identifying individuals involved in criminal activities. During his tenure in the Indian Civil Service, he initiated the practice of employing thumbprints as a safeguard on official records to mitigate the prevalent issue of signature repudiation during the year 1858. In 1877, in the vicinity of Calcutta, a system was implemented by him wherein fingerprints were utilized for the authentication of contracts and deeds. Additionally, he undertook the registration of fingerprints of government pensioners as a measure to deter the unauthorized collection of funds by individuals following the demise of said pensioners. Herschel implemented the practice of fingerprinting individuals upon their sentencing as a preventive measure against various fraudulent activities that were undertaken with the intention of evading incarceration.(Prahlow & Byard, 2012, p. 139)

Despite the formal implementation of the anthropometric system for criminal recognition, certain instances have arisen in which this system has proven ineffective in aiding the process of identifying criminals. Within a short span of time, the Darbhanga District of Bihar witnessed the occurrence of two instances involving the perpetration of professional robbery through the means of poisoning. The detective assigned by the police to investigate the matter reached a decision that the perpetrator responsible for both incidents was identical. The event was not an isolated occurrence; numerous comparable cases were documented in various regions of India. In the given situation, the British Government, under the leadership of Edward Richard Henry, the Inspector General of Police, recognized the need to develop distinctive identifying marks that were impossible to replicate to mitigate the likelihood of such incidents.

In 1873, Sir Edward Henry assumed the position of assistant magistrate collector within the Indian Civil Service. Subsequently, in 1891, he was appointed as the Inspector General of Police in Bengal. In 1893, he visited Galton and acquired knowledge in the field of fingerprint identification. Upon his arrival in India, he realized the need to utilize this distinctive form of identification as a supplementary tool for criminal identification. The suggestion was made to integrate thumb impressions into record slips, along with anthropometric data, as a means of eliminating ambiguous identification of criminals.(Prahlow & Byard, 2012, p. 139)

To achieve this objective, a committee was established and subsequently a resolution was approved by the Governor General in Council on June 12, 1897. The resolution mandated the implementation of fingerprinting as the official method of criminal identification across British India. This achievement represents a significant advancement in the utilization of scientific methods for the purpose of discerning information. The Bengal Fingerprint Bureau, also referred to as the Writers Building, Calcutta, was established in 1897, making it the first fingerprint bureau in the world. The primary objective of this bureau was to establish uniform

procedures for the documentation, identification, categorization, enhancement, and conservation of fingerprints.(Chatterjee, Sahil Kumar (1953).

In pursuit of this objective, two police Sub-Inspectors, Khan Bahadur Azizul Haque and Rai Bahadur Hem Chandra Bose, were designated to contribute to the progress in the field of fingerprinting. The fingerprint classification system, commonly referred to as Henry's System, was attributed to Sir Edward Richard Henry, their supervisor. However, it was in fact developed by them. Azizul Haque devised a mathematical equation that facilitated Edward Henry in organizing ten-digit fingerprint forms within a pigeonhole cabinet system, utilizing fingerprint sequences as the basis for classification. Another Sub-Inspector named Hem Chandra Bose contributed to the field by devising an expanded framework for subclassifying fingerprints, creating a telegraphic code for representing fingerprint impressions, and developing a system for classifying fingerprints using single digits.(Chatterjee, Sahil Kumar (1953).

4.7. Firearms, Explosives and Weapons

Despite implementing revisions to the Indian Penal Code 1860 and undertaking comprehensive legal reforms, the British authority encountered challenges in effectively governing the dynasty in a harmonious manner. Elizabeth Kolsky, in her book, observed a notable disparity between the existing criminal legislation and the various criminal acts prevalent in society. Kolsky aptly characterized this situation as "a place of lawlessness at the centre of law's empire".(Kolsky, 2010) A variety of novel criminal activities were documented, including the utilization of explosive devices, such as the introduction of nitro-compounds, which resulted in multiple detonations and bombings across various regions of the nation. Several explosions occurred in various regions of the country, including the detonation of two magazines at Nari Gorge and Kach on the Sind-Peshin Railway in 1888, as well as the explosion of a magazine at Shelabagh on the same railway in 1890.

The Indian Explosive Act was enacted and implemented on February 26, 1884, with the objective of establishing thorough rules pertaining to the production, retention, sale, transportation, and importation of explosives within the British Indian territory. (The Explosive Act, No. 4 of 1884) Following the occurrence of multiple explosions, several committees were established with the purpose of conducting thorough inspections and evaluations. The British government made the decision to designate the Superintendents of the gun powder factory in Ishapur and Kirkee as the Chief Inspectors of Explosives for their respective regions. This decision was made based on the suggestion of Sir Vivian Majendie, who held the position of Her Majesty's Chief Inspector of explosives in the United Kingdom. After realizing that the aforementioned framework was unsatisfactory, the government made the decision to establish the position of the first Chief Inspector of Explosives as an autonomous authority.

Major C. A. Myspratt Williams assumed the role of Chief Inspector of Explosives on September 9, 1898, with his headquarters located in Nagpur. In the beginning, the Chief Inspector of Explosives received support from the Superintendent and the Assistant Superintendent of the Ordnance Factories located at Ishapur and Kirkee. Subsequently, to enhance operational efficiency, an additional five offices were set up in Calcutta, Bombay, Agra, Madras, and Gwalior, along with three sub offices in Shivkashi, Gomia, and Asansol .(D. U., 2001.)

These various organizations endeavored to establish a network and enhance their expertise to offer scientific insights into explosives and potential factors contributing to explosions. The individuals specialized knowledge and skills were instrumental in conducting investigations pertaining to criminal activities involving explosions, as well as in the development of different provisions within the Explosives & Petroleum Act. Various departments developed guidelines for the safe management of explosive materials, thereby facilitating the utilization of such resources by law enforcement personnel during criminal inquiries.

4.8. Handwriting

During the period spanning from the late 19th to the early 20th century, several nationalist movements emerged, which posed challenges to the effective functioning of the British government. To counteract these protests advocating for independence, the British administration implemented stringent regulations. However, the most challenging undertaking involved the decipherment of confidential nationalistic documents pertaining to movements advocating for autonomy. Given the circumstances, the British administration recognized the need to set up a dedicated section for handwriting analysis.

The unit would assist in the processing of confidential documents pertaining to nationalistic matters. To fulfil this objective, the position of Government Handwriting Expert of Bengal was put in place in 1904. Mr. C. R. Hardless, who held the ranking of Superintendent in the Account General's Office, was subsequently selected to this role.(Prahlow & Byard, 2012, p. 148)

After a span of two years, the office was relocated to Shimla, with the Director of the Criminal Intelligence Department assuming responsibility for its operations. Throughout his time in office, Mr. Hardless's work can be categorized into three distinct areas. Firstly, he focused on the analysis of handwriting submitted in courts to gather evidence. Secondly, he provided expert advice to police officers during their inquiry of criminal offences. Lastly, he offered his expertise to other government officials in the form of insights related to departmental concerns. Over a period, the position held by Mr. C. R. Hardless was filled by Mr. F. Brewester, a police officer working in the Bengal Criminal Intelligence Department. He was tasked with scrutinizing the government's files that raised concerns.(Prahlow & Byard, 2012, p. 148)

During a period characterized by the prevalence of indigenous scents in the atmosphere, this department achieved its pinnacle of success. Consequently, this field of study was utilized in various other instances, encompassing both criminal

and civil litigation. In 1925, Mr. R. Stott assumed responsibility as the successor to Mr. F. Brewester in the Military Accounts Department. During the period of World War II, the scientific discipline in question assumed the role of clandestine censorship, encompassing tasks such as the detection of concealed messages through undetectable writing and the instruction of military personnel.

In 1944, Mr. V. O. J. Hodgson assumed the position and served until the conclusion of British governance in India. During World War II, the department's efforts in probing bribery and corruption in arrangements with the War and Supply Department of India experienced a surge in activity. The Special Police Establishment Act was enacted in 1941 and subsequently came into force in 1946 to serve the intended purpose. This department established the groundwork for conducting scientific inquiries in the field of criminal investigations.

4.9. Serology

The discovery of human blood groups was made in 1901 by Karl Landsteiner, an Austrian American immunologist and pathologist. Subsequent to this occurrence, within the context of British India, law enforcement officials encountered difficulties in discerning any instances of crimson markings at the site of criminal incidents, whether they originated from human or animal blood. To fulfil this stipulation and acknowledge the significance of forensic serology, the establishment of the Serology Department took place at 3 Kyd Street in Calcutta in the year 1912. Subsequently, on March 1, 1916, it underwent a name change and became known as the Imperial Serologists Department. The appointment of Dr. E. H. Hankin as Imperial Serologist took place. Subsequently, the entity underwent a name change to the Department of Serologist & Chemical Examiner under the jurisdiction of the Government of India. Since its establishment, this institution has been actively engaged in the domain of forensic serology.(Prahlow & Byard, 2012, p. 149)

The identification of blood groups was not right away established. In the past, the department did not conduct blood group analysis. Instead, the presence of red spots at crime scenes was examined to determine if they originated from human blood. The primary focus of the study was the examination, which was conducted using chemical methods rather than relying on any immunological processes. Medico-legal illustrations were obtained from various forensic science testing facilities across the nation. Following the completion of serological examination on the exhibits, asserts were compiled and subsequently transmitted to the relevant regulatory bodies. Furthermore, the institute conducted tests on cases pertaining to paternity disputes and illegitimacy.

This institute obtained and analyzed medico-legal cases from various state forensic laboratories, including Raipur, Jalpaiguri, Bihar, and Assam, for the purpose of criminal examination. The provenance of these exhibits was examined through the analysis of various stained materials, including garments, firearms, cells, hair, saliva, semen, soil, and diverse bodily fluids. In addition to the operations, it is worth noting that venereal disease (VD) serology has been one of the most ancient and significant divisions within this institute. Since its establishment, the diagnostic sections for venereal diseases have been developed with the purpose of not only diagnosing these diseases, but also ensuring the inside quality monitoring of the VDRL antigen and standardizing the production of VDRL antigen in the antigen production section.

To this day, this segment continues to be acknowledged as a genuine antigen for non-specific serological testing in the detection of sexually transmitted infections (STIs).(Prahlow & Byard, 2012)

The chemical testers and analysts possessed expertise in a range of processes that extend beyond the confines of chemistry, encompassing disciplines such as toxicology, microscopy, photography, and examination utilizing ultraviolet and infrared lights. The researchers confirmed the existence of both organic and

inorganic toxins in food, animal feed, and internal organs. They successfully identified the existence of blood on various items such as clothing, weapons, and objects associated with acts of violence, animal cruelty, and related offences.

Furthermore, they identified the composition of explosives that were utilized or planned for illicit uses. Microscopic examination of animal tissue and fabric was conducted, and the researchers also employed ultraviolet light to investigate the origin of dissipated records and the ink used on them. Additionally, they performed testing on specimens for the excise, customs, and other significant agencies of the state as part of their crucial duties. During their leisure time, they provided instruction to law enforcement personnel on the application of scientific methodologies for crime detection.(Prahlow & Byard, 2012, p. 150)

4.10. Footprint

Since the conclusion of the 19th century, the British administration has recognized the imperative need to ascertain the presence of footprints at the location of a crime. While it is indeed accurate that expert trackers were employed in specific regions of India to apprehend criminals, it is important to note that these trackers lacked literacy skills and were incapable of effectively employing scientific methods of investigation. In the region of Rajputana, trackers belonging to this group were commonly referred to as Khojis, while in Gujarat they were known as Pogis.

This nomenclature was particularly prevalent in the dry or arid regions, where the practice of tracking, referred to as "Khoj," was observed in various locations within British India. In the historical context of British India, there existed multiple occurrences in which footprints were found at crime scenes as an alternative to fingerprints. In the year 1909, G. W. Gayer, Inspector General of Police, authored a manual titled "Footprint: As an Aid to the Detection of Crime for the Police and Magistracy."

This publication included lithographic plates depicting footprints and aimed to provide a scientific approach to investigating footprints in the context of criminal identification. In the year 1915, a section known as Footprint was established within the CID Department of Bengal. The primary aim of this section was to offer scientific evidence by analyzing footprints for the purpose of criminal inquiry.(Prahlow & Byard, 2012, p. 151)

4.11. Counterfeiting of Currency and Forgery of Notes

During the latter part of the 19th century, the British government encountered significant challenges arising from the prevalence of currency and bank note forgery. Due to this rationale, well in advance of the establishment of the Note Forgery Department, the British administration exhibited significant preoccupation with the enactment of a novel bill pertaining to the counterfeiting of currency notes. With the onset of European colonization and the subsequent expansion of commerce and trading, the establishment of banks emerged to assume the responsibility of issuing what is now referred to as banknotes.

The banknotes were issued under the authority of the British Monarch. They served as the primary means of transaction for the general populace. In addition, banknotes served as a means of preserving wealth, as they carried the assurance from the Monarch that they could be redeemed for a commensurate amount of silver upon request at the financial institution. Additionally, they functioned as a means of oversight for lawful economic endeavors. This allowed the government to acquire comprehensive knowledge regarding the overall extent of financial operations within the nation, encompassing bank credit, savings, and other related factors.

During the latter half of the 19th century, the British Government was compelled to address the issue of counterfeit currency, which had become a matter of significant concern. The frequency of forged currencies has increased, with numerous reported cases involving the reproduction of counterfeit currency notes

using photography, suggesting deceitful intentions. However, according to Indian legislation, currency notes were not afforded protection against such acts of forgery.

The matter of Indian law's unsatisfactory state and the need for revision, modelled after the English Forgery Law, was deliberated at the governmental level. As a result, the Secretary of the Government of India's Legislative Department, in a letter dated September 26, 1898, put forth a proposition to modify the legislation pertaining to the falsification of currency notes and bank notes. Subsequently, the legislation was officially implemented and designated as the Currency Notes Forgery Act of 1898. (Currency Note Forgery Act, No. XII of 1899.)

In the early 20th century, India experienced a significant historical catastrophe that had profound effects on both Indian society and the global community. World War I stand as a significant turning point in the geopolitical history of the 20th century, resulting in a significant decline of the global economy. The historical event resulted in the decline and ultimate downfall of four prominent imperial dynasties, specifically those of Germany, Russia, Austria-Hungary, and Turkey. The war in India resulted in the emergence of a novel economic and political landscape, characterized by a substantial rise in defense spending. This increase was primarily funded through war loans, augmented taxes, customs duties, and elevated income tax rates.

During the period of war, there was a notable escalation in prices, with a doubling effect observed between 1913 and 1918. This surge in prices resulted in severe economic challenges for the general populace. Due to the significant economic depression, the general populace experienced difficulties in effectively addressing their daily needs in a way that was tranquil. Both impoverishment and hunger have been identified as factors that drive individuals to resort to fraud and engage in anti-social means of sustaining a living. Despite the implementation of the Currency Note Forgery Act of 1898, the act of counterfeiting banknotes continued to be a prevalent method of generating income for a significant portion of the population.

The British Raj faced a significant challenge in examining the crime of note forgery and identifying the individuals responsible for such conduct, considering the socioeconomic and sociopolitical context. In response to the devaluation of currency, the British Government implemented a robust measure in the year 1917 to combat this illicit activity. Furthermore, amidst the aforementioned considerations, it is noteworthy that the British authorities during the course of World War I exhibited a sense of caution regarding the potential utilization of counterfeit currency by Germans. This apprehension stemmed from the concern that such forged notes could be employed to inundate the market within the British Empire, thereby inducing economic instability. There were suspicions regarding the utilization of counterfeit notes for the purpose of procuring weaponry and compensating mercenaries and rebels. It was necessary to conduct an examination of this matter. Because of the ongoing conflict, the value of silver had already experienced a significant increase and continued to rise. During the war, the bombing of the Bombay harbor by Germans resulted in a sudden erosion of public trust in the empire and its currency. It is evident that in the event of a British defeat, their currencies would become devoid of value within the context of the new governing system. A surge in demand for currency occurred, leading to a significant influx of individuals to banks seeking to exercise their right to the sovereign guarantee and trade their currency notes for silver.

This situation resulted in a depletion of the silver stock held by the central bank, leading to a disruption in the market. As a result, Britain had to seek financial assistance from the United States to acquire silver and fulfil its obligations under the sovereign guarantee. This involved purchasing silver to compensate individuals who wished to exchange their currency for silver. The government exercised caution in verifying the authenticity of currency notes to prevent the exchange of valuable silver for counterfeit notes. This development reached its pinnacle in 1917 with the creation of the "Note Forgery Section." This specialized division was established with the purpose of identifying counterfeit banknotes submitted for

exchange and safeguarding the economy against the widespread use of forged currency.(D. U., 2001, p. 153)

The establishment of the "Note Forgery Section" under the Criminal Investigation Department, Government of Bengal was ultimately undertaken by the British. The primary aim of this branch was to discern counterfeit currency notes and promote the public's understanding regarding the identification of counterfeit currency. Furthermore, the government mints and security printing departments located in Nasik made efforts to identify instances of counterfeit currency notes within their own laboratories. These endeavors greatly assisted the British administration in effectively identifying forged currency notes for criminal investigation purposes.(D. U., 2001, p. 153)

4.12. Ballistics

In the Indian context, there exists considerable uncertainty surrounding the earliest mention of gunpowder and firearms. The reference of firearms in ancient India was first documented in Sukra Niti. The dating of Sukra Niti remains a subject of considerable debate. However, it is noteworthy that Sukra and his Laws were held in high regard during the period of the Mahabharata. Consequently, it can be inferred that his treatise on law, kingship, and weaponry predates the events of the Mahabharata. According to historical accounts, it has been documented that Brahma initially composed the law in a voluminous collection of one lakh verses. Subsequently, Sukra undertook the task of condensing this extensive body of legal text into a more concise form, resulting in a final version consisting of 2,200 verses.

The utilization of gunpowder and firearms can be traced back to one of the earliest documented periods.(SYED RAMSEY.) It is evident that ancient Indians possessed a high level of proficiency in the craft of manufacturing explosive substances. The entirety of the details and descriptions were recorded in the Sanskrit language. The presence of gunpowder in ancient times is substantiated by the two renowned manuscripts of Vishampayana, specifically Sukraniti and Nitiprakashika. In the text

Sukraniti, the author Sukracharya refers to gunpowder as agni-curna. The ingredients utilized in the preparation of agni-curna were readily available within the geographical boundaries of India. Based on existing inventory records, the development of gunpowder has been attributed to the Chinese. However, the ancient Sanskrit records provide evidence that Indians were the inventors of gunpowder and firearms prior to the Chinese.

The primary components utilized in the production of gunpowder are saltpetre, charcoal, and sulphur. The copious presence of saltpetre in the Ganges valley facilitated the convenient preparation of gunpowder.(SYED RAMSEY, p. 155) The historical utilization and dissemination of firearms, specifically cannon, within the ancient Indian subcontinent, can likely be attributed to the latter portion of the 15th century. Babur, the progenitor of the Mughal Empire in India, made significant contributions to the proliferation of firearms within the region. Nevertheless, it is widely believed that gunpowder technology was introduced to India during the mid-14th century. According to historical accounts, there is a prevailing belief that the introduction of firearms and gun powder occurred significantly earlier and is attributed to the Mongols. This assertion is based on the fact that during the mid-13th century, the Mongol Empire successfully conquered territories encompassing both China and certain regions adjacent to India. India did not have any legislation pertaining to gun control prior to the year 1857. Indian citizens could possess weapons of any calibre. Following the 1857 Revolt, Lord Lytton assumed the position of Viceroy of India in 1858. The Indian Arms Act of 1878 was implemented during the tenure of Lord Lytton. (The Indian Arms Act, No. XI of 1878.) Following the implementation of this legislation, it became prohibited for any individual of Indian descent to engage in the production, sale, possession, or transportation of firearms.

As per the legislation, it was mandatory for individuals in India who desire to possess a firearm to obtain a valid license for its ownership. Possession of an unlicensed firearm was subject to legal consequences, including the imposition of

a monetary penalty and a potential prison sentence of up to three years. During the period of British rule in India, the acquisition of firearms was under the control of the British authorities. The Indian Arms Act was enacted in 1877 and remained in effect until 1947. From the onset of the 20th century, several national movements emerged with the primary objective of liberating the nation from the constraints imposed by the British Raj. The intensity of these national movements increased following the conclusion of World War I, particularly in the period leading up to the onset of World War II.(Prahlow & Byard, 2012, p. 156)

The utilization of firearms experienced a notable surge throughout this period of armed conflict. The majority of illicit firearms consisted of either domestically manufactured weapons or readily accessible firearms within the local market. The ammunition utilized in these firearms was predominantly unauthorized. The prevailing sociopolitical unrest prompted the British administration to set up a dedicated section focused on ballistic control to prevent the improper use of firearms. Consequently, in 1930, the Calcutta Police Department established a Ballistic Laboratory and appointed a firearms expert. The expert's endeavors proved beneficial to the administration's efforts in criminal investigation. It is apparent that over the course of 80 years, the colonial administration implemented various forensic institutions throughout different regions of India with the purpose of identifying crimes and individuals involved in criminal activities.(Prahlow & Byard, 2012, p. 156)

5. Concluding Remarks

A viable approach to successfully assembling a complex jigsaw puzzle involves identifying the outermost pieces of the image and constructing the perimeter of the puzzle prior to filling in the interior pieces. The present chapter endeavors to construct a comprehensive understanding of the jigsaw border, which has been in existence since the seventeenth century until the mid-twentieth century. This understanding is achieved through an exploration of the interplay between science

and law, the emergence of facts, probabilistic reasoning, expert witnessing, and the conduct of scientists in the witness box.

Additionally, the chapter delves into the challenges posed by the adversarial system and the strategies employed to overcome these challenges. The evolution of scientific methodologies for identifying criminals was significantly reliant on auxiliary technologies, commonly referred to as 'technosciences.' The potential for data, correspondence, and transportation technologies to be utilized as tools for scientific crime detection was initially promising. However, it is unfortunate that these same technologies also possess the potential for criminal exploitation.

The 1857 rebellion had a significant impact, leading to the establishment of forensic authorities by the British rulers. These institutions brought about changes in the way crime tracking was conducted in India and the broader South Asian region.(Pati, 2010) The advent of various advanced scientific technologies and specialized knowledge in fields such as chemical analysis, anthropometry, fingerprint identification, serology, handwriting analysis, footprint analysis, forgery detection, and ballistics has significantly transformed the methods employed in identifying crimes, particularly in cases relying on eyewitness testimony and coerced confessions.

The establishment of imperial supremacy was instrumental in promoting this newfound scientific accuracy, which served the dual purpose of eliminating the perceived unreliability of rural testimonies in court proceedings and strategically advancing their colonial agenda by ensuring a more persuasive governance based on truth and equity.

CHAPTER IV

RELEVANCE OF FORENSIC SCIENCE IN ADMINISTRATION OF CRIMINAL JUSTICE IN INDIA

1. Introduction

Within the common law tradition, the judges presiding over trials and appeals bear the responsibility of admitting and evaluating incriminating expert opinion evidence. It is noteworthy that these judges primarily depend on the parties involved in the legal proceedings to provide the evidence for their consideration. The primary challenges faced by accusatorial criminal justice systems stem from their reliance on parties with varying resources and competencies. These challenges revolve around two key issues: how courts and fact-finders gather details regarding the authenticity, effectiveness, and conclusive value of techniques and derivative opinions, and how assertions based on scientific, technical, and experiential knowledge should be offered, challenged, and assessed by lay participants.(Edmond, 2012)

Due to various factors, litigants may not always possess the skill to furnish pertinent details regarding the credibility of expert opinion proof, let alone data that is unbiased and clarifying. Moreover, it is observed that legal professionals, particularly those well-versed in the common law tradition, tend to prioritize legal precedent, historical customs, and previous interpretations of regulations. Unfortunately, this inclination often overlooks the significance of technical expertise and scientific understanding.

The tandem of the common law's focus on individual cases, along with these elements, has played a role in the emergence of practices that lack consistency when dealing with identical kinds of evidence and problems.(Edmond, Cole, et al.)

In the context of criminal proceedings, there is a notable lack of utilization and acknowledgment of pertinent scientific and technical research, as well as established methodological strategies. This deficiency is evident in the limited invocation or citation of such knowledge by parties involved, expert witnesses, and jurors, and is further compounded by the infrequent discussion of these matters. The process of making admissibility decisions frequently relies on subjective judgements and perceptions that lack empirical evidence or scholarly validation. In addition to exacerbating these inclinations, judges have a tendency to sustain a strong belief in the effectiveness of their common law procedures, specifically the trial safeguards that aim to ensure precision and impartiality, as well as the capacity of jurors and appellate courts to objectively assess and scrutinize expert opinions, even when their probative value is uncertain.(Edmond & Roque, 2012)

2. Principles and Objectives in Law: An Outline of the Ideas Underlying the Accusatory Procedure

To commence, it is imperative to present an overview of the prevailing standards and goals that typically underpin accusatorial criminal trials with regard to the establishment of evidence. The central focus within the 'rational tradition' pertains to the accuracy of facts, often referred to as truth.[1] The majority of philosophers, analysts, and professionals, involving judges, underscore the paramount significance of rendering an accurate verdict, specifically incarcerating solely those individuals who are truly culpable of committing a crime.(Twining, W. (1994).

As a result, the allocation of the burden and standard of proof during a trial is structured in a manner that primarily places the hazards on the accuser, namely the state. Ideally, the system should prioritize caution, ensuring that individuals accused are granted the advantage of uncertainty.(Twining, W. (1994). Consequently, it is incumbent upon the state to establish each component of a crime with a high degree of certainty, surpassing any plausible doubts. On the other hand, it is a fundamental principle in the legal system that the individual facing accusations is to be regarded as innocent until proven guilty. Furthermore, in the majority of situations, the suspect is not required to undertake any actions or make any statements in order to defend themselves.

There exist supplementary and occasionally conflicting factors linked to the process of prosecution and evidentiary demonstration, including the apprehension regarding the impartiality and equity of legal hearings. The accusatorial trial encompasses multiple procedures that are intended to function as safeguards for the parties involved, particularly those charged. Individuals who are accused and subjected to legal proceedings are entitled to certain fundamental rights.

These rights include the right to be informed of the charges brought against them, the right to seek legal counsel, the right to examine and contest evidence, the right to be present during court proceedings, the right to cross-examine witnesses, the right to present their own witnesses and evidence, and the right to have certain types of unfairly prejudicial evidence excluded from consideration, among other rights. (Twining, W. (1994).

The minute fraction of cases that proceed to the courtroom are presented before juries consisting of individuals who meet the eligibility criteria although their composition may not always be fully representative. Alternatively, judges may preside over these trials. In the event of an execution, individuals typically possess the right to challenge their case on grounds of procedural lapses, injustice, or an alleged erroneous or unreliable verdict.(Burns, 2010)

In most legal jurisdictions, although occasionally subject to the discretion of the executive branch, there exists the possibility of additional examination of indictments even after all avenues for appeals have been pursued. This is particularly applicable in cases where new evidence comes to light.(Duff, 2009)

The pursuit of proficiency and impartiality is evident in the contemplation of the worth and applications of certain forms of evidence. Furthermore, there is a deliberation on the effectiveness of adversarial procedures, particularly when considering the unresolved uncertainties surrounding the capabilities of the fact-finding tribunal, in enabling a comprehensive evaluation of evidence. There exist numerous adjectival regulations that either prescribe or impose limitations on the inclusion and utilization of specific categories of evidence.

The implementation of measures aimed at curbing the utilization of hearsay, constraining the reliance on prior transgressions to deduce patterns of conduct, and imposing restrictions on various forms of subjective judgement exemplify instances of said provisions. The regulations pertaining to evidence and its applications are frequently characterized as admissibility regulations. In the past few decades, there has been a discernible trend in the judicial system towards a greater openness to evidentiary considerations.

This shift has been characterized by a notable relaxation of stringent exclusionary regulations, thereby fostering a more facilitative environment for the admission of evidence. Certain legal provisions have been altered through legislative enactments, while others have undergone modifications through judicial interpretations, reflecting the evolving socio-institutional considerations pertaining to enhancing system efficacy and effectively managing limited resources.(Edmond, REVIEW, et al.) Concurrently, it is noteworthy that the majority of esteemed judges express enduring faith in the jury system, particularly in relation to contemporary jurors.

As a result, it has been observed that judges and legislatures have been progressively liberalizing the criteria for admissibility in criminal proceedings, displaying a growing hesitancy to exclude ostensibly pertinent incriminating evidence.(Edmond, 2012) In numerous legal jurisdictions, a noticeable trend has emerged wherein the principles governing the admissibility of evidence have undergone a progressive shift towards a more permissive stance.

Formerly, these principles were construed in a manner that restricted the disclosure of information to the fact-finding body, commonly known as the tribunal of fact. This entailed limitations on the admission of evidence pertaining to prior indictments, evidence of similar occurrences, and hearsay, among others. Additionally, certain deductions, such as those concerning propensities, were curtailed when evidence was confined solely to matters of credibility.

Furthermore, restrictions were placed on drawing conclusions from an individual's silence in the face of allegations or the belated presentation of alibis during the prosecution process. However, these restrictions have gradually been relaxed or modified to promote the admission of evidence for reasons that were earlier impermissible.(Twining, W. (1994). p. 37) The inclusion of incriminating expert opinions is an integral component of this broader ethos.(Edmond, 2012)

The aforementioned principles, objectives, and developments encompass a spectrum of legally conventional obligations that are regularly observed in significant judicial decisions and the extrajudicial statements made by esteemed judges, lawmakers, and legal experts.(Ho, 2008) However, it is imperative to acknowledge that these standards or prescriptions should not be perceived as immutable and universally accepted principles.(Langbein, 2003) It is noteworthy that there exist dissenting perspectives of considerable importance. Populist criticisms pertaining to the criminal justice system, in conjunction with the advocacy efforts of victims' collectives, frequently denounce the legal safeguards

and entitlements extended to individuals accused of criminal offences.(Edmond, 2012, p. 270)

3. Forensic Science's Absolute Objectivity: A Nonsensical Viewpoint

The foundation of science is predicated upon the utilization of the scientific method.(Duncan, O. D., & Nagel, E. (1961). Commencing from a theoretical framework, scientists undertake the construction of experimental designs with the aim of refuting the theoretical construct. In the event that scientists are unable to disprove the theory, it becomes imperative for them to subsequently devise and establish an instrument or methodology that enables the practical implementation of said theory within a specific context.

Once this phase is attained, it becomes imperative for scientists to undertake subsequent inquiries to elucidate the presence of a positive correlation between the obtained outcomes and the fundamental theoretical framework. This empirical investigation will additionally establish the veracity of the observed outcomes, determining whether they indeed stem from the novel methodology or if they merely manifest as a consequence of an undisclosed variable or occurrence.

In a more specific manner, the field of science flourishes through the identification and examination of errors and deficiencies within asserted hypotheses. Upon the identification of an error, it is customary to proceed with the subsequent reformulation of a theory, followed by its subsequent validation through rigorous testing procedures.

The inherent periodic pattern observed in the realm of scientific inquiry, when extrapolated to its logical conclusion, may ultimately culminate in the establishment of a novel scientific principle, should a specific conjecture or theoretical framework prove impervious to refutation. In addition to the promulgation of novel legislation, the cyclical approach under consideration is poised to engender groundbreaking technological advancements.

The importance of error detection extends beyond the realm of refining laws and technology; it also plays a crucial role in assessing the validity of the techniques of analysis and experimentation utilized in scientific testing, thereby enabling the derivation of objective findings and conclusions. In general, a large proportion of scientific endeavors directly address the matter of error detection. Scientists readily acknowledge that the occurrence of errors, particularly those that manifest during the stages of assessment and experimentation, is an unavoidable reality. In summary, it is widely recognized within scientific communities that the practice of science necessitates the detection of errors. (Burke et al., 1993)

In contrast to the prevailing trend observed in numerous scientific communities, it is noteworthy that the forensic science community exhibits a distinct reluctance to publicly accept the subject matter pertaining to error detection. In response to inquiries regarding its purported precision, the community tends to engage in one of two courses of action. They exhibit a tendency to either engage in avoidance behavior by metaphorically burying their head in the sand, or alternatively, asserting an unwavering position of infallibility. Frequently, the community contends that its respective methodologies yield no errors.(C. C.-Stan. L. & P. Rev. 2004.) The concept of infallibility is not a recent development.(C. C.-Stan. L. & P. Rev. 2004, p. 393) The recurrent affirmations of infallibility presented herein are in stark contradiction to a multitude of empirical investigations that consistently demonstrate a non-negligible margin of error within the realm of forensic sciences.(Peterson et al.)

The attribution of assertions of infallibility can be ascribed to two historical factors. Initially, it can be observed that the forensic science community, through its assertion of the infallibility of forensic evidence, has provided the judicial system with a form of empirical evidence that aligns with the anticipated standards of scientific inquiry.(Mnookin, 2019) The present corpus of evidence, which is both robust and incontrovertible, exhibits notable disparities when compared to the

expert scientific evidence of the early 20th century.(C. C.-Stan. L. & P. Rev. & 2004, p. 393)

Furthermore, the field of forensic science has flourished and advanced within the framework of prosecutorial criminal legislation.(M. S.-Wash. & L. L. Rev. 2000.) Henceforth, in light of the onus of proof imposed upon the prosecution, the recognition of the rationality and inevitability of errors arising from scientific endeavors can potentially lead to catastrophic consequences.

This assertion holds veracity in instances where the prosecution's argument heavily relies on the identification provided by a forensic examiner. If a forensic expert were to provide testimony indicating that bite mark identifications exhibit a "false positive" error rate of 63.5% and a "false negative" error rate of 22%, it can be inferred that the examiner has successfully put in place a significant level of uncertainty.(Bowers, M. (2002)

Nevertheless, in the event that the forensic expert simply proclaims the absence of an identifiable or ascertainable error rate, it effortlessly safeguards the prosecution's responsibility to establish the defendant's culpability beyond a reasonable doubt. The observation highlights the tendency of the entertainment media to propagate the fallacious belief that forensic science is impervious to inaccuracies.(C. C.-Stan. L. & P. Rev. 2004, p. 393) In accordance with the scholarly insights of Professor James E. Starrs, it is posited that the prevailing mythical and infallible perception attributed to the field of forensic science may potentially impede the credibility of the community, if not already manifested.

Of paramount significance, this phenomenon will inevitably compel forensic practitioners to extend their professional opinions beyond the realm of scientific inquiry and their specific domain of proficiency, to align with the prevailing misapprehensions held by the general public regarding the field of forensic science.(Greenfield et al., 2002) The speculative deductions are highly likely to stimulate a greater number of inaccurate indictments, as it is a recurring pattern that

speculations made by forensic experts consistently tend to favor the prosecution's argument.(C. C.-Stan. L. & P. Rev. 2004, p. 393) The notion that forensic science is impervious to fallibility is misguided and does not align with the reality of a professional community that consistently proclaims adherence to scientific principles.

4. The Bond Between Science and Law

The interdisciplinary field of forensic science and law encompasses the application of scientific principles and methodologies to legal investigations and proceedings. It involves the utilization of various scientific disciplines, such as biology, chemistry, physics, and psychology, to analyze and investigate.(Wecht & Rago, 2005)

Inquiry is hereby made as to the precise nature of this relationship, and whether it may be aptly likened to any other known phenomena or constructs. Can this relationship be compared to the juxtaposition of oil and water, two substances that exhibit an inherent inability to blend or coalesce? Alternatively, can we perceive this relationship as akin to that of a harmonious union between spouses in an ideal matrimonial bond, wherein the two individuals seamlessly merge into a singular entity?

Alternatively, could it be posited that the situation represents a state of estrangement within a relationship that is progressing towards an expeditious dissolution or a protracted legal separation? Could it be postulated that the scenario is merely a manifestation of an endeavor to engage in seductive behavior? Alternatively, could this couple be engaging in a courtship phase, wherein they are actively involved in the process of dating and assessing the viability of a potential long-term commitment based on their shared interests and compatibility? Have there been any offspring thus far? Is this family, assuming its existence, characterized by functional or dysfunctional dynamics? Numerous inquiries appropriately besiege us at this juncture.(C. C.-Stan. L. & P. Rev. 2000.)

However, it is important to acknowledge that the contemporary experience of venturing into the realm of forensic science and law entails a profound and transformative connection between the two disciplines. This connection represents a novel and pioneering frontier, characterized by its innovative and advanced nature. The emergence of civilization can be attributed to the intricate interplay of four fundamental relationships with the universe, namely religion, philosophy, science, and law. It is prudent to contemplate these four elements as the fundamental underpinnings from which the societal constructs of civilization have emerged.(C. C.-Stan. L. & P. Rev. 2004, p. 11)

The presence of forensic science inside courtrooms and public safety organizations is often seen as a contemporary occurrence, attributed to the emergence of the esteemed field of forensic pathology and the accessibility of highly educated professionals such as criminalists, crime scene experts, toxicologists, and laboratory Ph.Ds. Indeed, it is worth noting that contemporary television programming has seen a surge in the popularity of forensic scientists, who have emerged as the most prominent and revered protagonists.(C. C.-Stan. L. & P. Rev. 2004, p. 11)

In an era characterized by the convergence of legal and forensic science, novel and significant methodologies are emerging to facilitate the pursuit of objective veracity. It is imperative to recognize the concerted efforts undertaken by our legal, scholarly, scientific, and governmental establishments across the nation, as they diligently endeavor to establish interconnections between various programs and professions. The pedagogical and logical objective that they both pursue is fundamentally straightforward and directed towards the safeguarding of liberty, which is rooted in our pursuit of verifiable truths. In this intellectual expedition, it is imperative to acknowledge that law, forensic science, and other disciplines do not encompass the entirety of human existence. However, the amalgamation of their scholarly examination has undeniably yielded significant pertinence and manifestly

evident utility in diverse contexts pertaining to criminal, civil, and familial justice endeavors.(C. C.-Stan. L. & P. Rev. 2004, p. 35)

The techniques and practical implications of forensic science, when examined from an interdisciplinary perspective and evaluated in relation to their outcomes in legal examinations and the establishment of facts, are emerging as a potent force in diverse endeavors aimed at achieving justice. The presence of such a force is readily evident within the realm of law and various other disciplines. However, the intellectual potency of forensic science and law has not yet attained its state of equilibrium, commonly referred to as the angle of repose.

Significant advancements have transpired within the realm of forensic science in recent times, prompting a collective endeavor by the nation to investigate novel scientific, legal, and academic approaches aimed at ascertaining verifiable truths.(C. C.-Stan. L. & P. Rev. 2004.) The principles pertaining to criminal responsibility are firmly ingrained within our collective moral consciousness, as they revolve around the notion that punishment is inherently linked to culpability. Consequently, it is deemed unjust to administer punishment in cases where the individual in question lacks the requisite blameworthiness.(C. C.-Stan. L. & P. Rev. 2004, p. 36)

However, an increasing skepticism has emerged regarding the ethical efficacy of the criminal justice system, as indicated by the inherent fallibility of our judgements and the potential prevalence of numerous undetected instances of wrongful convictions. The circumstances pose a significant challenge to the fundamental tenets of our established criterion of evidence, which, at its most optimal, is compromised by the disclosure of these findings.(Wecht & Rago, 2005, p. 37)

5. The Recent Technological Advancements Designed to Meet the Rigorous Demands of Forensic Investigations.

The potential for a paradigm shifts within the criminal justice system is likely to arise from the convergence of innovations in forensic science and the integration of novel technologies and methodologies that offer enhanced value to end-users. In accordance with Downes' law of disruption, it is posited that the rate of technological advancements follows an exponential trajectory, whereas social, economic, and legal frameworks tend to evolve at a more gradual pace.(Downes, L. (2009). The circumstance poses a considerable challenge to the introduction and implementation of novel technological advancements.

Downes' law highlights the rapid advancements witnessed in the realm of digital technology. However, it is pertinent to note that this principle (Wecht & Rago, 2005, p. 37)e extends beyond the digital domain and finds relevance in various other fields, particularly within the criminal justice system. To facilitate the regular implementation of novel forensic methodologies, it becomes imperative to establish new legislative frameworks and implement comprehensive quality assurance procedures.(Downes, L. (2009).

The incorporation of novel scientific advancements and technological breakthroughs in various fields such as microbiology, chemistry, and information technology has undeniably engendered a substantial surge in the requisition for forensic science services over the past few decades. In the event that novel technological advancements emerge, offering the potential to furnish pertinent information for the resolution of criminal activities, it is highly probable that an expeditious and fervent demand for its implementation shall ensue.

It is of utmost significance to acknowledge that within the scientific domains, novel categories of trace evidence have emerged as influential factors. These classes were heretofore not duly considered, either due to the absence of evidence or the unavailability of suitable methodologies to scrutinize said evidence. The emergence of digital forensic science has undeniably resulted in a paradigm shift, ushering in an entirely novel realm of trace classifications.

In contemporary times, individuals inhabit a milieu characterized by a fusion of physical and digital realms, thereby engendering the generation of tangible as well as virtual imprints. In the contemporary Indian context, it is an undeniable reality that digital traces have become an integral component of nearly all criminal investigations. Hence, it is of utmost importance for providers of forensic services to possess the capability to retrieve and analyze traces originating from a comprehensive array of digital sources.(Kloosterman et al., 2015)

The burgeoning need for forensic facilities can be attributed to the heightened understanding among end-users regarding the manifold benefits and applications of forensic science. Furthermore, this phenomenon has given rise to a discerning end-user who possesses the capacity to articulate their inventive requirements.(Kloosterman et al., 2015, p. 9) The latter aspect holds significant importance in order to ascertain the specific domains that require research and development (R&D) efforts and innovation. The primary objective should be to concentrate these endeavors towards furnishing investigators and legal professionals with expeditious access to data that is both pertinent and up to date. The attainment of triumph in the realm of forensic science throughout the preceding decades has not been without its attendant costs.

The growth in demand within the sector, coupled with the organizational framework of forensic institutes, has led to the emergence of grave backlogs and subsequent elongated turnaround times. The consequential increase in pressure on the operational aspects of organizations has resulted in an impediment to the sustained pursuit of innovation, thereby causing a delay in the anticipated paradigm shift. The fundamental issue at hand pertains to the prevailing condition wherein a majority of forensic science institutes operate as entities driven by financial considerations, thereby possessing constrained resources that are insufficient to accommodate the escalating demand in a substantial and expeditious manner.

While the allure of seeking methods to augment capacity is enticing, it is imperative to address the issue of backlog from a more foundational standpoint, one that is rooted in an examination of the function and effectiveness of the comprehensive criminal justice system.(Kloosterman et al., 2015) The preceding insights have brought about endeavors in innovation with the objective of amalgamating the field of forensic science with cutting-edge technology. This integration seeks to initiate the development of forensic platforms that facilitate a significantly more streamlined and effective investigation of evidentiary materials.

Furthermore, the forensic specialists have commenced their exploration into the potential avenues for enhancing the increased efficacy of the advanced methodologies employed within the laboratory setting. By virtue of furnishing comprehensive field solutions tailored to conventional circumstances, the integrated forensic platform not only facilitates the augmentation of specialized proficiency in intricate cases but also serves as an indicator for identifying instances necessitating supplementary inquiry.

This phenomenon ultimately culminates in a significantly enhanced utilization of relatively limited expertise and erudition, as it entails the substitution of a substantial quantity of routine instances with a reduced quantity of intricate instances.(Kloosterman et al., 2015, p. 9) Undoubtedly, a paramount prerequisite for the conception, construction, and execution of comprehensively unified forensic platforms resides in the possession of adequate fiscal means to undertake the indispensable research and development actions, as well as the requisite quality investigations.

Furthermore, it is imperative to consistently integrate cutting-edge technology into these platforms. The development of such technology frequently occurs beyond the purview of forensic science, necessitating its adaptation for forensic purposes through rigorous forensic scientific validation. The successful execution of this

attempt requires the adoption of an interdisciplinary framework, commonly referred to as the 'triple helix' model.

Within this model, the convergence of academic institutions, pioneering enterprises, and forensic specialists is imperative to foster collaboration and achieve desired outcomes. Ideally, the foregoing cooperation manifests in an international context and encourages solutions that possess a broad applicability across numerous nations. The implementation of a more globally oriented framework would undoubtedly facilitate the cultivation of greater potential for innovation, notwithstanding the inherent national character of judicial systems. The ongoing attempts within the European Union to establish a European Forensic Science Area (EFSA 2020) and within the United States to establish a Forensic Science Centre of Excellence hold promising prospects for fostering a more cohesive and interconnected framework. This framework would facilitate the emergence of integrated and internationally oriented forensic approaches, such as integrated platforms.(Kloosterman et al., 2015, p. 9)

6. Crime Scene Investigation and the Significance of Forensic Evidence in Determining Culpability

Forensic evidence has long been regarded as one of the most compelling forms of evidence that is admissible and subject to judicial scrutiny within the courtroom.(Freeman, N. J., & Punzo, D. L. D. (2001). DNA evidence, specifically, has long been regarded as the epitome of forensic processes in the eyes of jurors.(Clancy & Bull, 2015) Indeed, it has been observed that DNA possesses a more pronounced impact on the determination of culpability in comparison to other forms of non-DNA forensic evidence.

This finding serves as a testament to individuals' trust in the reliability and accuracy of DNA, as well as their conventional notions regarding its superior precision and discriminatory capabilities when contrasted with non-DNA forensic evidence. Consequently, the perceived risk of a fortuitous match is diminished when DNA

evidence is presented.(Thompson et al., 2015) The existing body of research has provided evidence suggesting that jurors tend to hold the belief that DNA evidence possesses a higher degree of reliability than it may actually possess, while simultaneously lacking a comprehensive understanding of its potential fallibility.(Findlay & Grix, 2003) Nevertheless, recent research has yielded findings indicating that the general populace holds a perception of forensic evidence as being inherently prone to inaccuracy and heavily reliant on subjective human judgement.(Ribeiro et al.)

In its entirety, the presence of erroneous perceptions or convictions regarding forensic evidence can yield profound ramifications, particularly in instances where flawed forensic analyses culminate in instances of judicial error. There has been a surge in scholarly attention towards comprehending the perspectives of diverse stakeholders within the criminal justice system, including but not limited to prospective jurors, judges, defense attorneys, and prosecutors, with regards to their perception of forensic evidence and their level of awareness regarding its inherent limitations.(Ling et al.)

The investigation of whether criminal justice participants possess a comprehensive comprehension of the boundaries of forensic evidence assumes particular significance in situations where alternative forms of evidence exist that may potentially oppose the extant forensic evidence, or in cases where the acquisition of forensic evidence is either unattainable or impractical. Previous research has elucidated that specific categories of forensic evidence are perceived to possess a higher degree of accuracy and objectivity in comparison to others.(Kaplan et al.)

Notably, a scholarly investigation(Kaplan et al.) has observed that DNA analysis and fingerprinting have been identified as the most precise forensic methodologies among the ten techniques assessed. Moreover, these two forms of evidence have been recognized as fundamentally valid in the report issued by the President's Council of Advisors on Science and Technology (PCAST). Nevertheless, apart

from the utilization of forensic evidence, there exist alternative forms of evidence that may be introduced in the course of a legal proceeding.

The subject of intrigue pertains to the comparative perception of forensic evidence in relation to eyewitness testimony. A plethora of scholarly investigations have unequivocally established that jurors possess a tendency to regard both eyewitness testimony and forensic evidence as highly robust and compelling sources of information for the purpose of making informed decisions in legal proceedings.(Lindsay et al., 1981) The phenomenon of eyewitness testimony holds a prominent position within the realm of legal proceedings, as it is widely regarded as a highly persuasive form of evidence that is frequently offered to jurors.

Throughout history, it has consistently been upheld as the benchmark against which other forms of evidence are measured.(Brewer et al., 2011) Furthermore, it is worth noting that individuals who were in closer proximity to the defendant at the time of the offence, and therefore had a greater level of acquaintance with the defendant, such as the victim themselves, may be regarded as more reliable in their accounts of the defendant's actions compared to spectator eyewitnesses. In fact, research has demonstrated that this particular type of witness familiarity with the defendant has a substantial impact on both the probability of reaching a conviction and the level of confidence associated with such verdicts, particularly when contrasted with situations where someone unfamiliar serves as a bystander eyewitness.(Sheahan et al., 2018) Nevertheless, it is a common occurrence for jurors to place undue trust in the reliability of eyewitness identifications, despite the fact that empirical evidence consistently demonstrates otherwise.(Wells et al., 2003) Indeed, it is worth noting that erroneous identification made by eyewitnesses stands as a prominent factor contributing to wrongful convictions. Statistical estimates indicate that approximately one out of every three eyewitnesses are prone to committing such errors.(Wise et al., 2014)

Numerous scholarly investigations have been conducted to assess the comparative potency of forensic evidence vis-à-vis alternative forms of evidentiary support. The phenomenon of eyewitness testimony has garnered significant attention within scholarly discourse, owing to its reputation as a highly persuasive form of evidence.(Wells et al., 2003) The impact of eyewitness testimony and forensic evidence on the degree of certainty regarding guilt is noteworthy, as forensic evidence tends to evoke greater levels of confidence.(Pearson et al.)

Furthermore, it is noteworthy to highlight that the aforementioned effects exhibited a greater magnitude when applied to offences of a graver nature. This observation implies that the introduction of DNA evidence in legal proceedings pertaining to highly consequential or injurious crimes may engender heightened levels of juror conviction in rendering guilty verdicts.(Pearson et al.) In the realm of legal proceedings, it is commonly observed that forensic evidence, particularly DNA evidence, is often regarded as possessing a higher degree of accuracy and is accorded greater significance in comparison to eyewitness testimony. This tendency is evident among mock jurors, who rely on such evidence to ascertain their decisions and to bolster their confidence in the soundness of said verdicts.(Skolnick & Shaw, 2001)

Schweitzer and Nunez (Schweitzer & Nuñez, 2018) posit that to enhance the applicability of existing literature within the courtroom setting, researchers ought to direct their attention towards scrutinizing the significance of various categories of evidence that are frequently introduced in criminal trials, with respect to jurors' perspectives and their subsequent judgements. The examination of the diverse attributes of evidence and their potential impact on juror verdicts holds significant value in comprehending juror behavior.

This inquiry not only enhances our understanding of the subject matter but also offers valuable insights to legal practitioners, including judges and lawyers. Armed with knowledge regarding the sorts of evidence that influence juror rulings in

different case scenarios, these legal professionals can make more updated decisions, thereby optimizing their professional performance.(Schweitzer & Nuñez, 2018) This assertion holds validity not solely in the context of verdicts pertaining to the determination of guilt, but also in the realm of juror sentencing.

Moreover, since the evidence offered during a trial is contingent upon the type of case at hand, it is imperative to scrutinize the impact of evidence in cases pertaining to offences that inherently differ in terms of the probability or likelihood of securing a conviction.

7. Making a Call to Employ Forensic Science

The prevalence of forensic science evidence in criminal proceedings is relatively low, not due to the absence of scientific contributions in these cases, but rather due to pragmatic considerations that restrict the gathering of such evidence.(Roberts, 2019) Specifically, in the event that the accused party expresses an intention to enter a plea of guilt, and there exists a level of trustworthiness between said party and their legal counsel, such that the likelihood of altering their stance subsequent to the expiration of the period designated for the accumulation of evidentiary material is minimal, it becomes unnecessary to undertake the arduous and costly task of formulating forensic scientific evidence.

Forensic science, as aptly articulated by Firth, is distinguished by its intrinsic connection to legal proceedings, embodying the notion of 'science harnessed in service of the pursuit of justice'.(Roberts, 2019, p. 472) It is unsurprising, then, that the initial choice to employ forensic science evidence is influenced by the organizational norms and pressures inherent in the criminal procedure, aligning with scientific inquiry to a lesser extent. The determination to pursue scientific aid is typically made by law enforcement agencies, albeit with potential involvement from legal practitioners and prosecution counsel.

The probability of amassing scientific evidence decreases over time, primarily because a significant portion of evidentiary material can only be acquired during the initial phases of an inquiry. Once crime scenes are cleared, garments laundered, injuries healed, or samples deteriorated, the window of opportunity becomes irretrievable.

The initial demand for the use of forensic science is influenced by a multitude of factors, encompassing the nature of the offence, the gravity of the offence, the robustness of additional evidentiary material in the case, and the exercise of investigative judgement and discretion. The evidentiary aspects of forensic science are intricately linked to specific classifications of criminal offences. In the context of drug-related cases, it is customary for law enforcement agencies to consistently employ scientific evidence to ascertain the specific nature and composition of controlled substances, thereby facilitating the identification process.

In the event when the charge pertains to the possession of cannabis and the defendant opts to enter a plea of guilty, the law enforcement authorities hold the prerogative to depend upon their own field test results as evidence. Conversely, if the defendant chooses not to plead guilty, the aforementioned items must be duly provided to a laboratory for comprehensive analysis. Burglaries are frequently subject to prosecution utilizing forensic science evidence, as it is plausible that various forms of trace evidence, such as glass fragments, footprints, clothing fibers, or other materials, may establish a connection between the defendant and the crime scene.(Roberts, 2019, p. 473)

Law enforcement agencies frequently gather empirical evidence in cases of severe nature, such as instances involving physical injuries and sexual offences. This practice undoubtedly signifies an enhanced inclination to allocate policing resources towards more abhorrent criminal acts. Furthermore, it is imperative to acknowledge that there exists a substantial potential for the field of science to offer valuable contributions in these instances. In instances where an accusation of rape

is made, it is common for police surgeons to conduct examinations on both the victims and the accused persons, resulting in the acquisition of evidentiary material. Nevertheless, it should be noted that the severity and intricacy of an offence do not necessarily serve as foolproof indicators of the merit in gathering forensic science evidence.

Police personnel possess a significant degree of working discretion, which extends to both broad contexts and more specifically to the realm of forensic science evidence. In certain instances, the prosecution may opt to solicit scientific aid considering scientific evidence presented by the defense. This phenomenon has the potential to manifest itself during the advanced stages of the proceedings. The preference to engage scientific assistance during these subsequent stages ought to be comprehended as a means of enhancing, rather than negating, the initial law enforcement choice to proceed with the case in the absence of forensic scientific evidence.(Roberts, 2019, p. 474)

8. An Examination of the Importance of Forensic Science by Means of its Foundational Standards

In contrast to other disciplines that have achieved a higher level of establishment, the field of forensic science currently lacks a comprehensive consensus and widespread acknowledgement regarding its core nature, objective, and fundamental principles. This groundwork has regrettably been disregarded, despite its acknowledgment by numerous esteemed pioneers in the field of forensic science, who have deemed it indispensable for the progress of this discipline. Forensic science is widely regarded as an indispensable pillar within the framework of the criminal justice system. This perspective is juxtaposed by persistent and occasionally substantial scholarly discussions regarding its efficacy and dependability that have emerged throughout the past ten years.(Margot, 2011) The discourse surrounding the subject matter has brought to light several pressing concerns that warrant careful examination and analysis. These concerns, which

have garnered significant attention and are subject to extensive deliberation, encompass various aspects such as the accumulation of pending tasks,(Synergy 2020.) the effective administration of quality control,(S. W.-S. & J. J., 2014.) the mitigation of inherent biases,(Cooper et al.) and the assessment and dissemination of empirical evidence.(Buzzini et al., 2019)

Numerous partial solutions have been posited throughout the course of time; nevertheless, the field of forensic science persists in a state of unresolved chaos, as evidenced by scholarly discourse.(Weyermann et al.) The present crisis can be attributed, to some extent, to the predominant utilization of institutional perspectives such as legal or different scientific domains in the presentation of most challenges, rather than adopting a lens rooted in the discipline of forensic science.

The proposition that the consideration of organizational aspects holds paramount significance is indisputable. However, as elucidated by Roux et al. in their seminal work,(Roux, Willis, et al.) the concepts of 'means' and 'processes' are intrinsically intertwined with the intricate web of local political and legal frameworks, which inevitably exhibit substantial variations across nations, territories, and institutions. Consequently, the identification and consensus on techniques that can be deemed 'universal' and possess enduring efficacy pose a formidable challenge.(Roux, Willis, et al.) To elucidate, the ongoing discourse has predominantly neglected the overarching objectives of forensic science and its fundamental subject matter, instead prioritizing the organizational and mechanistic facets of its application. The present juncture necessitates the transcendence of this impediment, a predicament that had been previously discerned by Kirk nearly six decades ago.

The present inquiry revolves around the characterization and definition of forensic science, as well as the examination of whether there exist adequate shared foundational principles to facilitate its evolution into a distinct discipline. These principles hold significant importance in driving progress within the respective

domain, encompassing education, training, research, and development, as well as operational practices.(Roux, Willis, et al., p. 680)

Numerous scholars have engaged in extensive discourse pertaining to the aforementioned inquiries, as evidenced by a multitude of scholarly works.(Sci. 1963.) Nevertheless, in contrast to disciplines that have achieved a higher level of establishment, the field of forensic science currently lacks a cohesive consensus and widespread acknowledgement regarding its core essence, as well as its overarching objectives, purpose, and fundamental principles.

In light of the stated rationales, a cohort of sixteen forensic scientists undertook a protracted period of introspection spanning multiple years, with the objective of delineating the discipline of forensic science and encapsulating its intrinsic nature through the formulation of fundamental standards in a succinct and all-encompassing manner.

9. Sydney Declaration

The Sydney Declaration endeavors to reexamine the fundamental underpinnings of forensic science, transcending the confines of organizational structures, technical intricacies, and procedural frameworks. The text encompasses a comprehensive explication of forensic science, accompanied by a set of seven cardinal principles that underscore the paramount significance of the trace as an indelible residue or fragment of a scrutinized undertaking.(Roux, Bucht, et al..)

The Sydney Declaration also expounds upon the salient characteristics that delineate the purview of the forensic scientist's endeavors, including but not limited to the contextual framework within which their work is situated, the inherent temporal asymmetry that pervades their analyses, the chain of uncertainties that permeate their findings, the imperative of possessing a comprehensive and extensive scientific acumen, the ethical considerations that underpin their

professional conduct, as well as the indispensable faculties of critical thinking and logical reasoning that inform their methodologies.

The contention posits that the suggested principles ought to serve as the foundation for the implementation of forensic science and provide guidance for the trajectory of education and research endeavors. In the grand scheme of things, the enhancement of forensic science's overall relevance, efficacy, and dependability will ultimately prove advantageous.(Roux, Bucht, et al.)

The Sydney Declaration encompasses a comprehensive explication of the field of forensic science, delineating its definition and presenting a set of seven core principles that serve to elucidate the essence and foundations of this discipline within a unified structure. These principles encompass the entire spectrum of forensic science, spanning from the initial inquiry of an offence to the ultimate manifestation of findings. The seven principles, as delineated, incorporate a comprehensive framework that serves as a guiding compass for understanding and analyzing the subject matter at hand. These principles, which have been widely acknowledged and accepted within the academic community, are:(Roux et al., 2022)

1. Activity and presence produce traces that are fundamental vectors of information.
2. Scene investigation is a scientific and diagnostic endeavor requiring scientific expertise.
3. Forensic science is case-based and reliant on scientific knowledge, investigative methodology and logical reasoning.
4. Forensic science is an assessment of findings in context due to time asymmetry.
5. Forensic science deals with a continuum of uncertainties.
6. Forensic science has multi-dimensional purposes and contributions.
7. Forensic science findings acquire meaning in context.

In the initial stages, it is imperative to acknowledge that certain individuals within the field of forensic practice may encounter challenges in comprehending the applicability of these principles to their respective professional endeavors. This phenomenon may particularly apply to professionals operating within specialized sub-disciplines, which are often perceived as distinct from the field of criminalistics. These individuals, commonly referred to as "analysts" or "technicians," may find their professional identity predominantly shaped by their routine responsibilities. The entity realm of forensic chemistry, it is commonplace for professionals specializing in drug analysis to undertake the task of assessing the identity and ascertaining the level of purity of drug specimens that are supplied to them for examine(Roux, Bucht, et al.)

The primary role of the entity in question can be described as that akin to an analytical chemist. From this vantage point, individuals may encounter challenges in perceiving the comprehensive worth and profound ramifications of the Sydney Declaration. In addition to fulfilling its inherent regulatory and investigatory obligations, forensic drug analysis possesses the potential to make valuable contributions towards enhancing our comprehension of the overarching drug predicament.

Illustrative instances encompass the identification and surveillance of areas exhibiting heightened drug-related activities via expeditious on-site examinations, the detection and gauging of the emergence of novel perilous drug combinations through the confiscation of substances from street operations and the examination of paraphernalia that has been destroyed or traded, as well as the decryption of the illegal market or a criminal network through the application of drug profiling techniques and the analysis of the digital drug marketplace. Numerous analogous observations could be posited with regard to myriad other sub-disciplines.(Roux, Bucht, et al.)

9.1. Delineation of Forensic Science as advocated in Sydney Declaration

The definition of forensic science as propounded in Sydney Declaration is stated below:

Forensic science is a case-based (or multi case-based) research-oriented, science-based endeavour to study traces – the remnants of past activities (such as an individual's presence and actions) – through their detection, recognition, recovery, examination, and interpretation to understand anomalous events of public interest (e.g., crimes, security incidents).(Roux et al., 2022)

The ostensibly uncomplicated delineation at hand belies a profoundly intricate scenario rife with myriad unregulated variables that inevitably exert influence upon the modus operandi of forensic science. The initial determinant pertains to the case, which can be legally delineated as a distinct offence or incident by the primary responder or the aggrieved party, predicated either on testimonies or on the preliminary perception derived from a given circumstance.

The initial corollary posits that the given case lacks the essential characteristic of being a reproducible experiment, thereby precluding the possibility of replicating its outcomes. Notwithstanding the existence of diverse recordings that may potentially facilitate the establishment of a chronological sequence and enhance the comprehension of various facets of the event or case, it is improbable that an event can be meticulously rebuilt in its entirety.(Roux, Bucht, et al.)

The second corollary posits that the event under consideration has transpired in a previous time frame or is presently unfolding. Hence, the temporal interval separating the occurrence of an event and the commencement of its investigation emerges as a pivotal determinant in the erosion of informational content, encompassing physical, digital, and mnemonic domains. Regardless of the

circumstances, forensic analysts initiate the probe by utilizing circumstantial evidence.

The event in question was delineated in such a manner due to a variety of factors that were taken into consideration during its conceptualization and subsequent definition. These factors encompassed a range of considerations, including but not limited to the event's objectives, scope, and intended audience. The process of defining the event involved a comprehensive analysis of these factors, which were carefully evaluated and weighed too. What are the assertions pertaining to the occurrences that transpired?

Is there empirical evidence available regarding the spatial orientation and location of objects, entities, and other physical entities? These various elements shall serve as guiding principles for the purpose of conducting observations and inquiries into pertinent evidence that may either challenge or refine the initial information from an alternative standpoint.(Roux, Bucht, et al.) Conversely, they may also contribute to the clarification and validation of the comprehension of the case at hand.

It is imperative to underscore that the term "trace" in this context should not be construed as denoting an entity of minuscule proportions that resides at the threshold of detectability by analytical instruments, as chemists often advocate. However, it is important to note that a trace has the potential to manifest in various forms, ranging from substantial entities like megaliths to minuscule particles such as gunshot residue. In some cases, traces may even assume an imperceptible nature, necessitating the utilization of specialized physical or digital instruments for detection.(Roux, Bucht, et al.)

The inclusion of the "research-oriented" component within the definition of forensic science is indicative of the inherent uncertainty surrounding the veracity of a given event. While suggestions may be put forth and victims may provide affirmation, the ultimate truth lies solely within the purview of the actor whose actions prompted the inquiry. Within the realm of historical discourse, literature has

traditionally been regarded as a repository of dependable knowledge pertaining to past events. However, it is widely acknowledged that the discipline of history is not immune to the inherent complexities associated with the malleability of human memory and the subjective perspectives of those who document historical accounts.

Consequently, the veracity of historical narratives may be subject to revision or distortion over time, as the lens through which historical events are perceived and interpreted by writers may introduce biases or inaccuracies. To mitigate these potential pitfalls, historians often rely on a diverse array of supplementary sources of evidence, such as archaeological artefacts (e.g., rocks, timber, pottery) and human remnants, to recreate factual elements that may not align with the narratives presented in historical writings.(Roux, Bucht, et al.)

The field of forensic science involves the examination of remnants and traces that are purportedly contemporaneous with the event in question. These remnants possess a tangible existence, thereby enabling their analysis, measurement, and comparison. The efforts of conducting measurements, assessments, and analogies does not guarantee the attainment of a singular and conclusive depiction of the events and individuals involved. However, the identification of specific positions and objects through these processes serves to constrain the range of potential causes, thereby facilitating the emergence of a plausible clarification for the investigation at hand.(Roux, Bucht, et al.)

The field of forensic science employs the systematic application of observation, analysis, and logic in order to interpret its findings within the context of diverse assertions pertaining to a given case. The acquisition of knowledge is facilitated through the process of discovery and subsequent scientific evaluation. One additional corollary that can be derived from the definition pertains to the indispensable requirement of the forensic scientist's proximity to the location where the event occurred. This proximity may manifest either through physical presence

at the scene or through the involvement of a trained third party in the early phases of the investigation, responsible for the evaluation and gathering of traces.

This introduces an additional element that contributes to the depletion of primary information, namely the constraints imposed by time and distance, which collectively serve to curtail the full potential that forensic science can provide. The definition elucidates two fundamental outcomes that can be derived from the field of forensic science: the process of ascertaining the identity of a subject and the explication of actions that may establish a connection between a specific recognized source and a particular outcome, the causal correlation of which may serve as a persuasive factor for an individual responsible for making a decision.

The utilization of the causal connection proves to be particularly advantageous in instances characterized by recurrent patterns, wherein serial or linked offenders are involved.(Roux, Bucht, et al..) Ultimately, this particular scientific discipline does not possess the characteristic of predictability commonly observed in the realm of physics. In physics, one can anticipate and forecast outcomes when designing an experiment. However, in this context, the science in question is retrodictive in nature, offering plausible elucidations for the existence of pertinent evidence.(Roux, Bucht, et al.)

The elucidation of this definition, along with the intricate circumstances it encompasses, engenders the opportunity for the formulation and progression of the ensuing seven cardinal principles.

9.2. Principle 1- Activity And Presence Produce Traces That Are Fundamental Vectors of Information.

One fundamental prerequisite for the commencement of a forensic science investigation resides in the inherent characteristic that no activities can transpire devoid of imparting discernible traces. The objects in question may exhibit two distinct outcomes: either they remain present at the site of interest, or they are

removed from said location, thereby adhering to the well-known principle of Locard's exchange. The inherent characteristics of the activity exert a significant impact on the various categories of items that are swapped, as well as the manner and spatial distribution in which they are disseminated within the surrounding environment. The aforementioned artifact(s), serving as a vestige of the scrutinized endeavour, can be identified as the trace. The trace, in its essence, embodies a vectorial representation of data that possesses the inherent capacity to be detected, retrieved, scrutinized, and subsequently comprehended through the process of interpretation. The phenomenon of traceability in human affairs is undergoing a rapid transformation within the context of our increasingly digitalized environment, characterized by the integration of physical and digital realms. The prominence of forensic science has become progressively pivotal in the examination of public events that are undergoing significant changes.(Roux et al., 2022)

The fundamental principle underpinning the delineation of forensic science is predicated upon the notion that traces, whether they be physical or digital in nature, serve as the elemental constituents of the evidence pertaining to an incident or a series of incidents. The trace, as denoted by scholarly discourse, can be understood as an enduring vestige, or remains that emerges from an activity that has undergone thorough investigation. The vestige, in its essence, serves as an indication of a previous existence or undertaking, thereby establishing a connection to its erstwhile affiliation and the modality through which it was relinquished as per the activity.(Roux, Bucht, et al., p. 5)

The initial identification of the trace, preceding its collection and subsequent laboratory examination, constitutes a pivotal element within the realm of investigative endeavors. To ensure the proficient identification and interpretation of traces, it is imperative for the forensic experts to duly contemplate the genesis of said traces. The formulation of the trace encompasses various pivotal elements that necessitate contemplation by the forensic scientist present at the location.

The aforementioned factors encompass the characteristics of the source, the characteristics of the trace, the surrounding environment, the procedure of exchange, the extent of persistence, and the temporal dimension. In the preliminary phases of a probe, it is imperative to pose pertinent inquiries that facilitate the understanding of the subject matter. These inquiries encompass the following: What is the inherent essence of the trace under scrutiny?

In what locations can these traces be situated? To which specific events do these traces unequivocally allude? and What is the intrinsic worth or significance of these traces? These inquiries play a pivotal role in the pursuit of comprehensively tackling broader matters pertaining to reconstruction of with whom or what and in what manner? Furthermore, it should be noted that these inquiries necessitate the inclusion of contextual details and a more comprehensive understanding of the subject matter pertaining to offence and the conduct of individuals involved in criminal activities.(Roux, Bucht, et al.)

The comprehension of the locomotion patterns exhibited by the entities responsible for generating traces, such as the accused, aggrieved, and object, within the given environment, can yield valuable insights regarding the prospective deposition of traces, as well as their probable locations and distinctive attributes. In the process of encountering, identifying, and acknowledging traces, it becomes imperative to ascribe them with significance.

To successfully discern between background traces inherent in the environment and those generated during the events under investigation, it is imperative for a forensic expert to possess a comprehensive understanding of the environment and its associated traces.(Sci. 1963.) The various components involved in the process of trace formation, identification, interpretation, and examination necessitate the forensic scientist to engage in contemplation regarding Kirk's principle of individuality.

When considering an object in its fragmented state, it is important to acknowledge its inherent distinctiveness in relation to its origin. As stated, "a thing can only be identical to itself and not to any other entities, as every object within the universe possesses its own individuality".(Sci. 1963.) In light of Kirk's proposition, the forensic scientist endeavors to progress towards distinctiveness by means of comparative analyses and the process of elimination. It is imperative to acknowledge that this undertaking is a procedural endeavor rather than a definitive objective.

The forensic scientist must exercise prudence in refraining from asserting 'matches' or absolute certainty in cases where such determinations are either unattainable or nonexistent. Given the forensic scientist's reliance on traces as a means of acquiring insights into past occurrences and operating within a historical context, it becomes apparent that the fragmented nature of both the traces themselves and the accompanying historical documentation poses a significant obstacle to achieving definitive conclusions in the process of reconstructing past events. Traces, in their ultimate manifestation, serve as indispensable conduits that facilitate the advancement of investigative and intelligence endeavors. The inclusion of traces, encompassing both tangible and intangible manifestations, within the broader structure of the criminal justice system, assumes a pivotal and indispensable significance.

The field of forensic science ought not to be exclusively driven by the pursuit of justice or litigation, but rather should encompass a broader scope that encompasses its potential contributions to policing, security, and the wider realm of criminal justice. This includes both practical aspects, such as crime prevention, as well as theoretical considerations, such as its relevance to criminological inquiries.(Roux, Bucht, et al., p. 4)

9.3. Principle 2- Scene Investigation Is a Scientific and Diagnostic Endeavor Requiring Scientific Expertise.

The primary objective of the scientific inquiry conducted at the site is to employ deductive reasoning in the face of inherent ambiguity, with the aim of reconstructing an event by meticulously examining the remnants that have endured. The location of an occurrence is where pertinent evidence can be identified and described in terms of their relative placement, which may provide insight into their sequence, orientation, and interaction. The aforementioned information synergistically contributes to enhancing comprehension regarding a finite set of plausible hypotheses pertaining to the discernible remnants, necessitating subsequent scrutiny and explication within the framework of the reconstruction and identification procedures. The intricacy at hand necessitates the expertise of an individual possessing a cultivated intellect, encompassing a comprehensive understanding of scientific principles, coupled with adeptness in the realms of observation and detection. Furthermore, the aforementioned skills may be augmented through the utilization of an array of scientific instruments and methodologies.(Roux, Bucht, et al.)

Crime scene inquiry and reconstruction represent the epitome of intellectual rigor and seeking endeavors within the realm of forensic science.(Encyclopedia of Law Enforcement - Google Books.) Regrettably, the process of conducting scene "investigations" has been diminished to a mere technical effort focused solely on the retrieval of overt evidence, such as fingerprints and bloodstains.

This approach neglects the intellectual and analytical aspects that demand scientific interpretation, encompassing a broad spectrum of factors that cover the specific event being investigated to the inherent characteristics of the traces themselves. Within the current structure, the predominant focus lies in the realm of crime scene processing, wherein the primary activities involve the systematic and repetitive procedures of documenting, collecting, and preserving various traces encountered at the scene of the crime.

Merely amassing items from a given scene in a haphazard manner, without due consideration for factors such as their spatial arrangement and dispersion vis-à-vis other objects, their spatial orientation, their mode of production and the mechanisms governing their movement and preservation, as well as their importance and their interrelation with the very act under scrutiny, falls short of sufficiency.(Encyclopedia of Law Enforcement - Google Books.)

The process of reconstructing events through the deciphering of traces necessitates a foundational comprehension of the semiotic signs and their underlying meanings. Merely monitoring the trace in isolation does not suffice for the trace to attain relevance and manifest as a sign encompassing its full range of potential meanings within the field of semiotics.(Roux, Bucht, et al., p. 4)

The presence of the trace is indeed evident; however, its comprehension necessitates the process of decoding, or rather, the act of interpretation facilitated by an interpreter. Put simply, the ability to explicitly identify and comprehend traces, as well as employ inferential reasoning to decode and attribute meaning to said traces within the context of the given task, such as a criminal investigation, necessitates a broad foundation of knowledge. Forensic investigations are commonly conducted to examine events that occur at a specific site or scene, resulting in the generation of a natural record of actions. This record is composed of various element traces.

Upon the recognition, examination, and interpretation of the resultant traces, one can derive significant scientific insights pertaining to the event that engendered them, thereby facilitating a comprehensive comprehension thereof. Traces are generated in accordance with inherent natural principles. The production of the record is subject to the constraints and influences imposed by natural laws.

The possession of scientific expertise is imperative in order to optimize the process of extracting pertinent information and to facilitate the formulation of logical inferences based on the available traces. It is imperative that the individual tasked

with conducting scene investigations possesses the qualifications of a scientist, encompassing a profound comprehension of pertinent natural principles. The forensic expert relies on the fundamental scientific framework to effectively apply natural laws in the process of investigating and recovering significant traces.

The pivotal role in scientific scene inquiries is fulfilled by the generalist forensic experts, who possesses a wide-ranging scientific acumen complemented by an extensive understanding of forensic science, trace evidence, criminal investigations, and criminal behavior. It is imperative that forensic scientists with a broad range of expertise attend the scene of a crime from its inception in order to conduct a comprehensive investigation.

Considering the various technological advancements that can be effectively employed within a given location, it remains imperative to acknowledge that the acknowledgment, significance, and interpretation of traces necessitate the indispensable involvement of human agents, who rely upon scientific knowledge and reasoning to carry out these tasks.(Roux, Bucht, et al.) The analysis and reorganization of a crime scene necessitates the involvement of a forensic scientist who possesses a comprehensive understanding of the subject matter, acquired through formal education, specialized training, and practical experience.

This individual should be capable of conducting thorough inquiries and effectively conveying their analytical reasoning and methodology to various stakeholders, including law enforcement officials, jurists, and laypersons. Furthermore, the scientist should be proficient in examining and interpreting traces found at the crime scene, recognizing their significance within the larger context of the criminal investigation.(Roux, Bucht, et al., p. 5)

9.4. Principle 3- Forensic Science Is Case-Based and Reliant on Scientific Knowledge, Investigative Methodology and Logical Reasoning.

Traces, in their essence, can be regarded as manifestations of signs, and the field of forensic science, in its pursuit of knowledge, employs a rigorous scientific

methodology to scrutinize and comprehend the significance of these signs, taking into account their inherent inconsistencies, potential misinterpretations, and inherent strengths. This scholarly endeavour entails the act of posing pertinent inquiries, which are predominantly contingent upon the context at hand, engaging in astute observations, formulating hypotheses, and subsequently subjecting said hypotheses to rigorous examination and evaluation.1The testing may encompass measurements that are facilitated by technological means; however, it is imperative to acknowledge that these tests merely serve as an extension of the scientific process. The procedure is distinguished by the application of critical thinking, the utilization of logical reasoning, the engagement in problem-solving endeavors, and the exercise of informed judgement. The efficacy of this approach is compromised, and potentially even negated, in the absence of its application within a coherent conceptual framework employing a comprehensively established investigative technique.(Roux et al., 2022)

Upon comprehending the trace as the primary object of our scientific curiosity, it becomes imperative to deliberate upon the forensic science methodology, specifically the way science actively engages in an inquiry or a legal determination. The objective of Principle 3 is to elucidate the process of forensic science, encompassing four fundamental notions. Firstly, it addresses the significance and constraints associated with testing. Secondly, it emphasizes the necessity of a coherent framework and an investigative technique. Thirdly, it underscores the interpretation of traces as indicative signs. Lastly, it highlights the imperative of employing critical thinking, logical reasoning, problem-solving skills, and informed judgement. The subsequent discourse delves into the elucidation of these concepts.(Roux, Bucht, et al., p. 4)

1. The conduct of testing may encompass the utilization of technological apparatus for enabling measurements; however, it is imperative to acknowledge that these tests merely serve as an augmentation of the scientific process. The imperative for a scientist to employ dependable

examines and measurements is a matter that elicits no contention. Nevertheless, it is essential to acknowledge that the testing methodology is incapable of serving as a viable replacement for the intricate and rigorous scientific process. Tests can be regarded as instrumental devices akin to magnifying glass, the COVID-19 antibody test, the telescope employed by astrophysicists, and so forth. The entities do not comprise the scientific framework or the foundational knowledge upon which the test is predicated. Scientific instruments serve as an extension of the sensory capabilities possessed by scientists, enabling them to discern and quantify various characteristics, measurements, or results that are anticipated to provide significant insights and pertinent data. The current state of technology has reached a level of refinement such that it consistently provides outcomes that are dependable in terms of their accuracy and precision. The presence of ambiguities in a given context is often attributed to the inherent variability observed in traces, which can be assigned to factors such as inhomogeneity and the limitations associated with statistical sampling, among others.(Roux, Bucht, et al.) Regrettably, the predominant emphasis in attempts pertaining to quality lies in the realm of tools, rather than in the augmentation of the procedure from its inception. Numerous laboratory facilities employ the practices of standardization, accreditation, and certification as a means to compensate for their inherent limitations in terms of identification, acquisition, and pertinence. The product exhibits a disproportionately high-cost relative to its efficacy, thereby rendering it an imprudent investment. Furthermore, its transient nature engenders outcomes that are inherently unsatisfactory in nature.(Roux, Bucht, et al.) At this juncture, it is imperative to address the pivotal query: does this formalism possess the requisite capacity to substantiate inquiries and effectively respond to the inquiries posed by adjudicators of fact? Has the efficacy of forensic science experienced an increase in contrast to its

reliability subsequent to the implementation of measures such as standardization, accreditation, and certification? The second point elucidates the problem.

2. The efficacy of the forensic science approach is compromised, and potentially even hindered, in the absence of its application within a coherent system and the utilization of a comprehensively recognized investigative technique. Undoubtedly, the matter at hand exhibits characteristics indicative of a broader or metacognitive quandary. In essence, may we enhance the system through a concentrated examination of methodologies and performance metrics, particularly in relation to the error rate, given that the primary sources of uncertainty pertain to the specific circumstances under investigation and the associated traces? The augmentation of intricacy via the implementation of verified laboratory quality controls is a pertinent consideration.
3. Traces, in their essence, embody indications that warrant scrutiny, and the field of forensic science, in its pursuit of knowledge, employs a rigorous scientific methodology to scrutinize and comprehend the significance of these indications, taking into account their inherent inconsistencies, potential misinterpretations, and inherent strengths. This entails the act of posing pertinent inquiries, which are predominantly contingent upon the contextual framework, engaging in astute findings, constructing propositions, and subsequently subjecting said propositions to rigorous examination and evaluation.(Crispino et al., 2021) The primary objective of a forensic analyst is to assist a decision-maker, such as a judge, jury, law enforcement, or examiner, in making a decision that carries inherent risks. The individual responsible for making decisions must attain a satisfactory level of conviction regarding a reconstituted historical narrative, encompassing inquiries into the identities, actions, locations, temporal aspects, associations, and methodologies involved. In the context of this

case-centric methodology or individualized undertaking, the primary responsibility of the expert in forensics is to assess the extent to which traces may serve as evidentiary support for the ultimate arbiter. The present methodology exhibits a certain degree of ambiguity, further compounded by the widespread utilization of the ubiquitous term "evidence". The trajectory of the path, denoted by the sequence of trace, sign, clue, and proof, may not always adhere to a linear progression. Rather, it undergoes a multifaceted metamorphosis through the process of logical deduction.(Crispino et al., 2021) Nevertheless, it is imperative to recognize the inherent necessity of embracing the investigative procedure in this approach. This acknowledgement holds significant relevance not only for the scientist but also for their overarching mission, which ideally rests upon a foundation of robust and pertinent scientific knowledge. Recognizing this formidable task compels us to comprehend the inherent ontological ambiguity of traces and the boundaries of our deductions, necessitating a harmonious equilibrium between transparency and the forensic scientist's institutional standing, customary practices, methodologies, and limitations.

4. The forensic science operation is distinguished by the application of critical thinking and rational thought, encompassing deductive, inductive, abductive, and analogical modes of inference(Schuliar, Y., & Crispino, F. (2013). The approach causes the facilitation of resolving problems and the cultivation of judgements that are well-informed.

The preliminary stage exhibits a lack of singularity and can be perceived as a perpetual oscillation amidst diverse cognitive operations. The primary cognitive framework employed within the discipline of forensic science is that of hypothetic-deductive reasoning. In the realm of serial crime, the identification of analogous patterns between two ostensibly unrelated cases, yet characterized by identical modus operandi, unveils the manifestation of reasoning by analogy.

The inherent nature of human cognition encompasses logical reasoning and inferential processes, which serve as the fundamental pillars underlying scientific advancements. However, it is imperative to thoroughly comprehend and systematically classify these cognitive procedures within the realm of forensic science. The rationale behind the inherent nature of inconsistencies in forensic science stems from the fact that each case is essentially a research problem. Consequently, a comprehensive and multifaceted approach is required, supported by a robust abductive element that may be comparatively less prominent in other scientific pursuits.

Principle 3 emphasizes the fundamental role of perception and interpretation as the primary vehicles for signification and meaning. Consequently, it recognizes the presence of a semiotic dimension within the foundational framework of reasoning in the field of forensic science.(Crispino et al., 2021)

9.5. Principle 4- Forensic Science Is an Assessment of Findings In Context Due To Time Asymmetry.

In numerous cases, the fidelity of the trace produced by an activity is such that it is deficient, flawed, and/or deteriorated due to temporal progression, thereby augmenting uncertainty and frequently necessitating reliance on mere approximations pertaining to the historical event being examined. The verifiable and definitive reality persists within historical epochs and is predominantly elusive. The utilization of forensic science is limited to the construction of a descriptive model that elucidates a particular scenario, predicated solely upon observed phenomena. The consideration of context is of paramount importance in this discourse. The present model under consideration is not of a general nature, but rather a specific retrodictive model that is inherently inferential in its design. The determination of the precise conditions surrounding a trace is a task that forensic scientists are unable to accomplish with absolute certainty. Instead, their role is to evaluate the relative significance of the findings that are linked to the trace,

considering various plausible causes or scenarios. The evaluations ought to exhibit impartiality and be grounded upon the principles of scientific rigor and transparency.(Roux et al., 2022)

One of the salient attributes inherent to the field of forensic science lies in its preoccupation with the meticulous reconstruction of historical incidents or activities. Given the inherent impossibility of temporal regression, the process of reconstruction necessitates reliance upon residual vestiges engendered by the activity or event under scrutiny. The verifiable and definitive reality persists within the realm of historical events and is impervious to retrospective examination. The application of reasoning is employed in an effort to ascertain the underlying causes by analyzing the observable effects. The process of reconstruction in the given situation inevitably entails inherent uncertainties due to the logical reasoning employed.(Roux, Bucht, et al., p. 5)

A singular occurrence or undertaking yields a plethora of imprints or consequences. The concept of temporal asymmetry can be conceptualized as a conical structure, wherein the consequences stemming from a particular event propagate outward from the point of origin in a temporal manner. Prior to and after the focal event or action, there are also extraneous actions or events that transpire and produce supplementary traces. One of the primary obstacles lies in the discernment of pertinent traces as opposed to those that lack relevance within a specified context.

Post-event occurrences that are unrelated or inconsequential not only generate supplementary evidence, but also have the potential to alter the primary evidence, thereby adding further complexity to the process of reconstruction. Furthermore, it is important to acknowledge that the passage of time can potentially lead to the deterioration or modification of the traces of interest. Several of these extraneous actions pertain to the tasks executed by initial responders and law enforcement personnel.

In instances where such circumstances arise, it is imperative that the forensic scientist be granted unrestricted access to comprehensive accounts delineating said actions, thereby facilitating the process of reconstruction. The ability of forensic scientists to ascertain the precise circumstances pertaining to the source of a specific trace is inherently limited, thereby precluding the establishment of unequivocal conclusions. Events or actions frequently give rise to a plethora of traces or ramifications. Considering the above circumstances, it is imperative that the attempts pertaining to reconstruction take into account a multitude of remnants, while simultaneously considering the contextual factors at play.(Roux, Bucht, et al.)

Forensic experts possess the capability to develop a retrodictive model, thereby enabling the evaluation of the relative significance of correlated observations within various probable causes or situations. In order to establish a cohesive narrative, it is imperative to explicate the reasoning models employed in this reconstruction, as well as the obstacles they entail. These principles provide a comprehensive account of said models and challenges.

Forensic science, without question, does not stand as the sole scientific discipline engaged in the meticulous reconstruction of historical occurrences. The said disciplines are commonly referred to as the historical sciences, encompassing fields such as archaeology, paleontology, and astronomy.(Roux, Bucht, et al.)

9.6. Principle 5- Forensic science deals with a continuum of uncertainties.

The field of forensic science encompasses a spectrum of ambiguities that manifest at each stage of the procedural trajectory, commencing with the inception of traces and progressing through all subsequent phases until the dissemination of findings and their significance to the designated recipient, whether conveyed through written documentation or oral means, such as their exposition within a legal setting. Further investigation is imperative in order to discern and measure these

uncertainties, bearing in mind the inherent nature of uncertainty as an enduring presence that cannot be entirely eradicated.(Roux et al., 2022)

The incorporation of unpredictability and their effective handling constitute an inherent component of the discipline of forensic science. As elucidated in Principle 4, the veritable veracity pertaining to an occurrence persists in the annals of history, albeit it can be emulated via empirical investigation and subsequent reconstruction. Moreover, it is imperative to acknowledge that uncertainties are an inherent facet of the deductive reasoning employed within the realm of forensic science. Uncertainties manifest themselves from the very inception.

As explicated in Principle 1, the process of trace generation serves as the fundamental framework for the reconstitution of historical occurrences. In accordance with the principles of natural sciences applicable to the present era, it is important to acknowledge that the trace in question is inherently deficient, flawed, and subject to degradation over time. Consequently, these inherent limitations contribute to heightened levels of uncertainty or, at best, enable mere approximations to be made regarding the historical occurrence in question.(Rossy et al., 2017)

The criticality of reconstructing alleged activities lies in the presence of several key factors. Firstly, the generation of traces is of utmost importance. These traces serve as tangible evidence that can shed light on the activities in question. Additionally, the ability for traces to be transferred between different regions or spaces is crucial.

This enables the tracing process to extend beyond a single point of reference and provides a broader perspective. Furthermore, the persistence of traces within a specific location or space is vital. Without their endurance, the ability to reconstruct alleged operations would be severely hindered. Equally significant is the detection and recognition of traces. This entails the identification and acknowledgement of these traces as relevant pieces of evidence.(Rossy et al., 2017) Moreover, the recovery of traces from their respective locations or spaces is a fundamental step in

the reconstruction process. Without this retrieval, the potential insights that these traces hold would remain inaccessible.

Subsequently, the examination, analysis, and comparison of traces play a pivotal role. These activities allow for a comprehensive understanding of the alleged activities, as well as the relationships and patterns that may emerge. Lastly, it is essential to have knowledge of the background abundance of traces. This contextual understanding provides a benchmark against which the significance of individual traces can be assessed. In conclusion, the aforementioned factors collectively contribute to the ability to reconstruct alleged activities.

Nevertheless, it is critical to acknowledge that these factors exhibit a significant degree of variability, as they are contingent upon the specific circumstances surrounding the case at hand and are predominantly devoid of any intentional manipulation or regulation. Hence, it is vital to recognize that inherent uncertainties pervade each stage of the process, rendering their complete eradication unattainable.

Nevertheless, it is important to acknowledge that these uncertainties possess the potential to be discerned and measured via diligent scholarly inquiry, ultimately leading to their effective mitigation in real-world applications. Regardless of the level of rigour exhibited by the validated method, it is necessary to acknowledge that the analysis and assessment of the trace may necessitate revision in light of emerging information or propositions that align with the parameters of the case.(Roux, Bucht, et al., p. 6)

The conduction of research plays a crucial role in establishing the parameters of ambiguity that arise in the field of forensic science. This enables the thorough exploration and maximization of the informational capacity of traces, encompassing their proficient interpretation and assessment of their evidential worth within the contextual framework of a purported event scenario.

Furthermore, it is imperative to underscore the significance of research in enhancing our comprehension pertaining to the various facets of trace generation, movement, retention, deterioration, identification, and approval.(Roux, Bucht, et al., p. 6) Although conducting a research project for every individual case is not feasible, the accumulation of knowledge derived from scenario re-enactment and modelling, when applicable, forms a solid research-oriented groundwork that can be employed to evaluate a multitude of ambiguities.

The establishment of authentic datasets, wherein specimens with established origins, ages, and/or levels of degradation are systematically analyzed and examined using analytical methodologies, can provide valuable insights into the limits of detection and enable the evaluation of related inconsistencies. The fundamental component of the forensic science process involves the meticulous assessment and evaluation of specimens obtained from various sources such as the crime scene, aggrieved, accused, and other pertinent locations and individuals.

These specimens are then compared to reference samples in order to recreate the alleged event scenarios. The process of conducting a comparative evaluation can encompass two distinct approaches: one involving objective measurements with quantifiable ambiguity, and the other relying on subjective measurements with less well-defined uncertainties that are contingent upon calibrated expert knowledge and experience. An example of the former approach is the examination of a novel psychoactive drug, wherein it is compared to a known reference substance. In this case, objective measurements can be employed, and the ambiguities associated with these measurements may be determined and validated.

Conversely, the latter approach involves subjective measurements, such as an analogy of tool marks, patterns on projectiles, footwear marks, or fingermarks. In these instances, the inconsistencies are less precisely defined and are reliant upon the expertise and knowledge of calibrated experts.(Roux, Bucht, et al., p. 6)

The comprehension of the challenges linked to the interpretation, assessment, and dissemination of analytical results is a fundamental element within the forensic science procedure. This research necessitates an exploration of transferability, the enduring nature of phenomena, cognitive predispositions, the cognitive processes underlying decision-making, and the effective dissemination of scientific knowledge.

The paramount objective for the field of forensic science is the effective dissemination of its outcomes within the judicial system, a necessary step to ensure that the fact-finder comprehends the significance of the scientific evidence in their decision-making process.(Roux, Bucht, et al., p. 6) In addition to the judicial realm, there are inherent obstacles associated with effectively engaging with the diverse array of users and stakeholders within the field of forensic science.

These individuals encompass a wide range of roles, including detectives, intelligence analysts, law enforcement administrators, as well as armed forces and other government officials. The present discourse pertains to the essential of conducting research on forensic science ontologies in order to facilitate public involvement with science. Additionally, it necessitates an exploration of the realm of science interaction, encompassing both written and oral modes, within the diverse contexts that bear relevance to this subject matter.(Roux, Bucht, et al., p. 6)

The incorporation of virtual reality and augmented reality into record-keeping and training, alongside the utilization of artificial intelligence, machine learning, and deep learning algorithms for tasks such as analogy, identification of patterns, and decision-making processes, has witnessed significant advancements in various fields beyond the realm of forensic science. Notably, these technological advancements are swiftly gaining traction within select domains of forensic science, such as DNA analysis and digital inquiry.

Nevertheless, it is imperative to ensure the integration of these advancements into the field of forensic science in a manner that is both suitable for its intended

objectives and compliant with legal frameworks. The validation of enacted approaches and calibration of related unpredictability necessitate the undertaking of research on various aspects, including collecting data, preservation, compilation, assessing, comparison, scrutiny, dissemination, ethical practices, biases, and risk in decision making.

In any event, it is important to note that these approaches do not purport to supplant the role of the scientist, as human involvement remains indispensable.(Roux, Bucht, et al., p. 6)

An auspicious prospect presents itself for the reconfiguration of the research culture within and across the domain of forensic science by means of interdisciplinary engagements between practitioners in the field and scholars in academia. Enhancing one's comprehension of deviant and criminal conduct in order to elucidate the intricacies of traces, and conversely, represents a conspicuous illustration.

The technological viability of fostering an open science culture, wherein the untapped reservoirs of data within forensic science laboratories, such as historical casework, organizational databases, and libraries, are made accessible, is evident. The present era is characterized by the availability of open data sets, which offer scientists the opportunity to employ comparable procedures and methodologies in their seminal investigations, such as those pertaining to dissemination and persistence.

This facilitates the amalgamation of data sets, thereby augmenting their efficacy and utility, thereby representing a significant and worthwhile undertaking.(Cadola et al., 2021) In a similar vein, the adoption of citizen science methodologies, specifically in the realm of background abundance studies, holds great potential for significantly enhancing comprehension, interpretation, assessment, and ramifications of trace elements.(Synergy 2020., p. 320) This would allow for the

precise delineation of inconsistencies and the implementation of efficacious reconstructions.

The methodologies have exhibited remarkable efficacy in the realm of public healthcare and environmental change research, thereby substantiating their viability. In the realm of forensic science, it is evident that all of the above strategies lie within our purview, albeit necessitating a sense of coherence and effective guidance.

9.7. Principle 6- Forensic science has multi-dimensional purposes and contributions.

The multifaceted nature of forensic science necessitates an exploration of its manifold objectives and contributions. Forensic science, by means of a methodical examination of evidentiary remnants, serves as a conduit for the acquisition of erudition pertaining to criminal activities, illicit markets, and sundry mechanisms that engender detriment or elicit societal apprehension. Furthermore, it bestows its invaluable contribution upon incident inquiries and furnishes indispensable support in the realm of legal adjudication, thereby facilitating the process of decision-making. Forensic science serves as the fundamental scientific underpinning for the execution of diverse functions and occupations pertaining to criminality, deviant behaviour, and societal reactions.(Roux et al., 2022)

The advent of digitalization has resulted in a significant increase in both the quantity and variety of traces being generated.(Casey et al., 2019) Principle 6 underscores the significance of forensic science in formulating methodologies that enable a robust, equitable, and commensurate "scientific" administration of this novel traceability of events of significance within wider security and criminal justice frameworks.

Principle 6 categories the multifaceted nature of objectives and contributions into three distinct subsets. These entities are characterized by the presence of

overarching structures of a global nature that serve as guiding principles for the interpretation of information. Of particular significance is the manner in which conclusions and decisions are made within various operations, each with its own unique set of objectives. The prevailing paradigm in the field of forensic science involves the utilization of traces primarily for the purpose of bolstering decision-making processes within legal proceedings, wherein the assessment of traces is contingent upon the presence of well-constructed assertions. This perspective encompasses the broad spectrum of legal and regulatory frameworks governing various facets of human endeavors.(Roux et al., 2022)

The culmination of a diverse criminal inquiry process is the trial, which is initiated upon the detection of indicators suggesting the occurrence of a noteworthy event.(Roux et al., 2022) Upon conducting a meticulous examination of forensic practices, it becomes evident that a mere fraction of the various traces gathered from a crime scene ultimately find their way into the judicial proceedings.(Ribaux et al.)

The majority of the presented details is typically utilized in the initial stages of the investigative process. The operational activities are conducted with the purpose of achieving diverse objectives, including but not limited to ascertaining the veracity of a criminal incident, detecting, tracking down, and apprehending the alleged offenders, conducting interviews with witnesses and suspects, and providing guidance for numerous additional investigative endeavors.

At the commencement of an inquiry, there exists a paucity of information pertaining to the subject matter under scrutiny. Within the context of this perplexing scenario, it is imperative to underscore that the analysis of traces primarily assumes a qualitative nature, wherein it becomes a cognitive endeavour involving the faculties of imagination and the formation of associative connections between ideas. The primary objective of this endeavor is to cultivate alternative explanations that will gradually form a comprehensive framework for organizing and guiding further

inquiries. In addition to the invaluable contributions made by forensic scientists, a multitude of individuals actively engage in the collaborative endeavor of fostering knowledge and data. To ensure adherence to legal and procedural regulations, as well as pragmatic considerations such as timeliness and the inherent limitations of accessible resources, it is imperative that they maintain compliance.

The symbiotic relationship between forensic investigation and evaluation is contingent upon their integration within distinct paradigms and cultural frameworks. Nevertheless, to enhance the evaluative aspect of interpretation, it is imperative to leverage robust forensic examinations from the very beginning.(Ribaux et al., 2015)

The field of forensic science has the potential to align with various policing models that extend beyond the conventional reactive law enforcement approach. Policing strategies that exhibit proactive characteristics, such as intelligence-led or problem-focused approaches, tend towards eliminating the occurrence of criminal activities, the mitigation of injury, and the suppression of criminal behavior.

These frameworks leverage the spatial and temporal clustering of deleterious incidents in order to discern trends in criminal activities. The evaluation and comprehension of traces play a crucial role in facilitating the identification and examination of recurring issues, thereby providing substantial assistance to combating crime efforts within the expansive framework of the criminal justice system.(Morelato et al.) The formalization and operational implementation of this type of integration can be observed in an expanding range of trace-based investigation systems. Illustrative instances can be found in diverse domains, including but not limited to, the realm of high-volume criminal activities, the realm of cybercrime, the field of sundry illicit markets, the arena of firearm utilization, the realm of prevalent fire causation and inception, and the domain of identity document falsifications.(Morelato et al.)

In a broader context, the practice of trace characterization serves to elucidate the underlying mechanisms that contribute to various manifestations of criminal activities and detrimental occurrences, which transpire within both physical settings and computerized facilities. It is apparent, therefore, that the amalgamation of various criminological approaches, such as environmental criminology and trace-based approaches, holds the potential to generate novel models and methodologies for the examination of crime and disorder.

Consequently, this integration serves to solidify the role of forensic science as an essential partner to the realms of crime investigation and mitigation.(Morelato et al.)

9.8. Principle 7- Forensic Science findings acquire meaning in context.

In order to uphold the integrity of their discipline, forensic scientists must adhere to a set of ethical principles, namely neutrality, transparency, and autonomy. These principles are crucial in ensuring that the data they furnish for the purpose of resolving the matter under inquiry is both valuable and dependable, irrespective of the parties who stand to gain from the details provided. In the realm of forensic science, it is imperative for practitioners to undertake the onus of defending their findings and perspectives in a manner that is both fitting and judicious, all the while demonstrating a willingness to recognize and acknowledge any probable alternative viewpoints. In the process of assessing outcomes, it is imperative to consider a minimum of two alternative assertions.(Roux et al., 2022, p. 81)

The significance of forensic science results lies in their contextual interpretation rather than in any inherent value they possess. The principle possesses significant ramifications and encounters varying degrees of acceptance within the wider scientific association and among stakeholders in the field of forensic science, including legal professionals and law enforcement members. It is imperative to delve into the underlying reasons that may account for this phenomenon.

The pivotal role of forensic science outcomes in legal processes cannot be overstated, as they are frequently erroneously regarded as unequivocal in their own capacity.(Roux et al., 2022) The fallacious perspective fails to acknowledge the profound influence of contextual factors. The proposition posits that scientists who generate such results ought to be subjected to a state of isolation from all external information sources as a means of mitigating potential biases.

Disregarding the presence of bias would be an imprudent course of action. However, it is imperative for forensic experts to discern between the influences of extraneous data that can be mitigated and the context-specific details that is indispensable for attributing significance to the obtained results. The lack of readiness to acknowledge the influence of context can lead to a conflation of extraneous data, resulting in biased interpretations and the omission of crucial contextual findings required for the accurate comprehension and interpretation of meaning.(Roux et al., 2022)

To effectively discern between the aforementioned resources of data, it is imperative for the scientist to possess a robust ethical framework. Furthermore, it is of utmost importance for the scientist to refrain from engaging in biased interpretation of their results to cater to the preferences or inclinations of the receiver of said information.

The uniformity of information, encompassing the contextual influence, ought to remain invariant irrespective of the addressee. The scientist is required to substantiate their conclusions while demonstrating a willingness to acknowledge plausible alternatives. Although the proposition may be expressed succinctly, it is imperative to acknowledge that implementing such a methodology entails a considerably greater level of complexity compared to merely reiterating the outcomes in a detached manner.(Roux et al., 2022)

Scientists bear an ethical responsibility to uphold their expertise, which encompasses the imperative to remain abreast of the influence of contextual factors

on research outcomes. Hence, it is crucial for a forensic expert to possess a comprehensive understanding of transmission, tenacity, and background information, as these elements constitute a fundamental component of their understanding base in the context of result dissemination.

It is important for the scientist to exhibit transparency in their correspondence and possess the ability to effectively elucidate the methodology employed to reach their results, encompassing the incorporation of contextual information to provide a framework for their interpretation.(Roux et al., 2022) It is a commonly observed phenomenon within the field of forensic science that practitioners seldom operate in isolation. During scrutiny, a forensic expert presents outcomes that may possess a speculative nature, albeit constrained by the laws of nature, and collaborates with the team investigating to examine the impact of contextual factors. During the evaluative phase, it is of utmost importance that the scientist effectively conveys the impact of context when providing guidance to the decision-maker.(Roux et al., 2022)

The righteous forensic scientist must possess a sense of equilibrium and autonomy. Collaborative efforts remain permissible within this context, albeit contingent upon the foundation of one's conclusions being firmly rooted in empirical evidence and scientific expertise. While the fundamental values remain invariant, the acquisition of information and data is subject to perpetual updates and revisions.

The dynamic nature of contextual data stemming from the inquiry presents a formidable obstacle for forensic scientists, as it necessitates the preservation of impartiality and effective dissemination of outcomes. The framework for achieving this objective involves the consideration of the probability of outcomes within a minimum of two alternative situations.(Roux et al., 2022)

10. Relevance of Forensic science in Criminal Justice Administration in India

The field of Forensic Science, which involves the utilization of scientific methodologies and strategies in the pursuit of justice, has a long-standing history in the ancient nation of India. The ancient texts and writings contain numerous references to fingerprint patterns, including Chakra (representing circular whorls), Sankh (symbolizing loops), and allusions to poisons, poisoning, and associated indications and symptoms. Indeed, it is worth noting that fingerprints have been employed as a means of authentication, particularly in the context of land deeds and similar legal documents. Furthermore, it is noteworthy that this practice persists in contemporary times, with individuals across the nation still utilizing fingerprints as a method of identification.(D. Ubelaker, 2015)

The development of laboratories dedicated to the examination and recognition of poisons in cases of poisoning can be traced back to the inception of the Chemical Examiner's Laboratory in Madras in 1849. This was subsequently followed by the setting up of similar laboratories in Calcutta in 1853, Agra in 1864, and Bombay in 1870.

It is noteworthy, however, that the Forensic Science Laboratories, as they are recognized in contemporary times, emerged at a later period with the creation of the West Bengal State Forensic Science Laboratory in Calcutta in 1952. The establishment of the Anthropometric Bureau in Calcutta in 1892 marked a significant development in the realm of criminal record-keeping, as it aimed to meticulously document pertinent information about offenders based on the principles outlined by Bertillon's System.

The establishment of the Fingerprint Bureau in June 1897 in Calcutta marked a significant milestone as the pioneering initiative of its kind globally. The establishment of the Government Examiner of Questioned Documents took place in Shimla in the year 1906. The establishment of the serology laboratory in Calcutta in 1910 marked a significant development in the field of forensic science in India.

This laboratory was designated as the official serologist to the Government of India, entrusted with the responsibility of examining various biological samples such as blood and semen. The establishment of the Ballistics Laboratory in Calcutta in 1930 falls under the purview of the police department.(D. Ubelaker, 2015, p. 149)

The volume of segments, or subjects encompassed, exhibits variability across different laboratory settings. The classifications that predominantly manifest in India include:

- Ballistics and Explosives Division
- Biology Division/DNA Profiling Unit
- Chemistry Division
- Computer Forensic Division
- Toxicology
- Criminalistics/Instrumental Analysis
- Fingerprint/Footprint Division
- Forensic Psychology Division/Lie Detection
- Document Division
- Physics Division
- Photo/Scientific Aid Division
- Serology Division.

11. The Management and Oversight of the Laboratories Administrative Functions

The managerial oversight of the Laboratories exhibits variations across different states, as well as within the Central Forensic Science Laboratories.(D. Ubelaker,

2015, p. 149) The Central Forensic Science Laboratory in Delhi is administered by the Central Bureau of Investigation, whereas the remaining Central Forensic Science Laboratories situated in Calcutta, Chandigarh, Delhi, Hyderabad, Pune, Bhopal, and Guwahati fall beneath the jurisdiction of the Directorate of Forensic Science based in Delhi.

The majority of State Laboratories are subject to administrative oversight by the Police, while a subset of these laboratories is under the direct control of the Department of Home.(D. Ubelaker, 2015, p. 149) The Departments of Forensic Medicine, which operate under the jurisdiction of the Ministry of Health and Family Welfare, are predominantly engaged in the performance of post-mortem assessments to ascertain the underlying cause of death. Additionally, these departments undertake the evaluation of victims and perpetrators to determine the nature and origin of injuries inflicted. Furthermore, they are responsible for imparting education to both undergraduate and postgraduate students through the delivery of various courses.

The significance of research is subordinate and predominantly grounded in case studies. Despite the presence of state-of-the-art instrumentation in the majority of laboratories, the advancement of scientific research has been impeded due to a dearth of appropriately skilled personnel and limited financial resources.(Misra & Damodaran, 2010) In its annual report for the year 1998-1999, the National Human Rights Commission, led by the esteemed Mr. Justice M.N. Venkatchalia, made an astute observation regarding the protracted nature of criminal cases. These cases, already subject to delays stemming from various factors, are frequently subjected to further postponements due to the unresolved status of matters within Forensic Science laboratories. The circumstance has introduced an additional obstacle to the administration of justice. Recognizing the paramount significance of enhancing the operational efficacy of the Forensic Science Laboratories, given its indispensable role in facilitating the effective administration of the criminal justice system, the commission deemed it imperative to investigate the challenges that plague these

laboratories. The objective of this inquiry is to formulate comprehensive guidelines aimed at optimizing their operational efficiency.(Misra & Damodaran, 2010)

Notwithstanding the constraints, notable progress has been achieved in resolving a considerable number of cases that are periodically submitted to the laboratories. Moreover, it is worth noting that a significant proportion of state laboratories are equipped with multiple Regional Forensic Science Laboratories. These regional facilities are strategically positioned to cater to various districts, while Mobile Forensic Science Laboratories are deployed to ensure efficient crime scene visits.

These mobile units play a crucial role in tasks such as collecting, packaging, and transmitting exhibits to the nearest Regional Forensic Science Laboratory or the central laboratory. This approach is particularly advantageous as it ensures that exhibits are promptly analyzed in facilities equipped with the necessary resources for the specific type of evidence under examination.

The Central Forensic Science Laboratories receive financial support from the central government, whereas the State Forensic Science Laboratories are financed by their respective state authorities.(D. Ubelaker, 2015, p. 152)

Recent advancements in technology have opened novel avenues for conducting rigorous scientific examinations and investigations beyond the confines of controlled laboratory settings. The advantages conferred by the utilization of real-time, on-site technologies are manifold. The field of forensic inquiries encompasses a wide range of methodologies and techniques, which possess the inherent capability to significantly enhance the expediency and effectiveness of the criminal justice system.

Nevertheless, it is imperative to acknowledge that the advantages can solely be actualized under the condition that a consistent assurance of quality is upheld perpetually, alongside the ability to utilize said discoveries as admissible forensic evidence within the judicial system. There exists a pressing necessity to cultivate

comprehensive forensic services that facilitate the meticulous examination of human biological evidence, the chemical discernment of illicit drugs, and the thorough analysis of substantial volumes of digital evidence.

These platforms facilitate the execution of field investigations, resulting in the acquisition of reliable and verified evidence. Moreover, they facilitate the strategic utilization of forensic intelligence and the intended deployment of expert resources available at forensic institutes. The advent of this technological revolution within the field of forensic science has the potential to bring about a significant shift in the prevailing paradigm.

This shift would entail the emergence of a novel role for forensic experts, wherein they would assume the responsibilities of both developers and custodians of unified forensic platforms.(Kloosterman et al., 2015)

12. The Convergence of Science and Technology within the Realm of Forensic Science.

The utilization of technology can be perceived as an indispensable propellant in facilitating the transformation of scientific discoveries and understandings into novel forms of innovation. The inherent value of scientific endeavors becomes tangibly realized through the application of technology, thereby facilitating society's complete utilization of novel discoveries. The benefits exhibit considerable diversity, encompassing a wide range of areas such as health, economics, commerce, transportation, communication, long-term viability preservation of cultural heritage, security, privacy, and justice.

However, it is worth noting that these advantages share a common characteristic in that they contribute to the enhancement of quality of life and foster societal advancement and prosperity. It is important to acknowledge, however, that these benefits must be weighed against the possible risks and hazards that may arise from abuse and threats linked to novel scientific discoveries.

The underlying justification for the significant and systematic allocation of resources by developed nations towards scientific initiatives lies in the interdependent cycle of science, innovation, and economic expansion. From a comprehensive and overarching standpoint, it is indeed intriguing to delve into the intricate interplay between technology and the field of forensic science. Contemporary forensic institutions are equipped with cutting-edge laboratories wherein evidence is meticulously examined utilizing state-of-the-art instrumentation.

Devoid of the frequently sophisticated and costly apparatus, the forensic specialist would find themselves incapable of producing the forensic conclusions that frequently bear paramount significance in the resolution of criminal cases and the provision of judicious adjudications within a court of law.

In an ideal scenario, the development of new technology should be tailored to suit its application in forensic studies. This entails ensuring that the technology is designed and optimized to facilitate its accredited and effective utilization within forensic laboratories. Moreover, it is crucial to determine the proof value of the technology, thereby solidifying its capacity to contribute to the forensic investigation process.

Additionally, the incorporation of criminalistic application into the technology's framework is imperative, as it enables the generation of meaningful insights and conclusions within the forensic domain. The amalgamation of scientific exploration, technological progress, and forensic implementation and analysis finds its most conspicuous and remarkable manifestation in the realm of contemporary forensic short tandem repeat (STR) DNA profiling.

The augmentation of value in the linkage between the forensic laboratory and the crime scene can be significantly enhanced, particularly in instances where field methodologies yield not merely suggestive information, but instead yield substantial and reliable data and discoveries that can be right away employed as

evidentiary support within a court of law. Nevertheless, the utilization of forensic techniques in non-controlled laboratory settings by inexperienced forensic practitioners necessitates significant technological endeavors.(Kloosterman et al., 2015)

Ensuring the perpetuity of finding's quality is imperative, necessitating the equipment's ability to function seamlessly amidst fluctuating and adverse circumstances, while concurrently exhibiting a high degree of user-friendliness. The fulfilment of these needs can only be achieved through the utilization of technology. Consequently, it is imperative that endeavors be directed towards the implementation of automated forensic analysis which would effectively address the reporting of ambiguities and mitigate the occurrence of potential errors that may arise from human operators. The utilization of wireless communication holds the potential to serve as the foundational framework for the establishment of a forensic platform dedicated to quality assurance, centralization, and evaluation of data acquired from a multitude of field devices.

The advent of this technological advancement within the realm of forensic science has the potential to instigate a profound shift in the prevailing paradigm. Consequently, a novel function for the forensic expert may arise, wherein they assume the responsibilities of both evidence analyzer developers and custodians of converged forensic platforms.

The incorporation of forensic proficiency and interpretation into the development of evidential value algorithms and quality control procedures serves as a fundamental component of the methodology employed within the discipline of forensics. Within the context of the criminal justice system, the scenario has the potential to facilitate the establishment of a collaborative interdisciplinary forensic platform. This platform would enable expeditious and highly effective examination of evidence by case officers, while simultaneously benefiting from the remote expertise of forensic specialists.

13. Integration of Forensic Laboratory and Crime Scene Technology

In the year 2009, Microsoft External Research put forth a comprehensive perspective on the forthcoming trajectory of scientific endeavors, thereby introducing the concept of the fourth paradigm in the realm of scientific inquiry, which is centered around the exploration of data-intensive scientific discovery(Tolle et al.). The advent of computational science has facilitated the transition from empirical experimental science to theoretical science, owing to the integration of computers into scientific research methodologies in recent decades.

The foundation of the fourth paradigm is predicated upon the remarkable proliferation of data accessible to researchers, facilitated by the expansive advancement of scientific endeavors on a global scale, and the subsequent dissemination of discoveries via interconnected networks spanning the globe. According to Microsoft's perspective, the establishment of a sustainable electronic infrastructure has the potential to effectively expedite the production of scientific knowledge through its facilitation of novel methodologies pertaining to data collection, modelling, exchange, presentation, extraction, and preservation.(Kloosterman et al., 2015)

Novel methodologies for data acquiring encompass the utilization of sensors and sensor networks, enabling the collection of scientific data on an unparalleled magnitude, both in terms of its voluminous nature and its ability to capture intricate details pertaining to time and space. In contemporary scholarly discourse, a plethora of scientific investigations pertaining to wireless sensor networks have surfaced, elucidating sensor technology, network architecture, communication protocols, data accumulation, and platform security. Sensor networks are utilized in the realm of tracking and monitoring applications.

Tracking networks are utilized in various domains such as military operations, animal conservation efforts, and logistical systems. On the other hand, monitoring networks serve purposes in areas such as patient monitoring within healthcare

settings(Alemdar et al.) as well as observing environmental situations and weather patterns(Capella et al.). In the context of sensor networks, it is customary to employ nodes that possess inherent limitations in terms of their measurement capabilities. These nodes typically exhibit a capacity to ascertain a solitary or restricted range of physical or chemical parameters. Examples of such parameters include, but are not limited to, climate, pressure, oxygenation, and conductivity.

A novel wireless sensor network has been developed for the purpose of online monitoring of water quality. This network incorporates the utilization of ion specific electrodes, enabling the concurrent measurement of nitrate, ammonium, and chloride ions.(Capella et al.) To enhance the capacity for acquiring comprehensive physical, chemical, and biochemical data, it is imperative to establish interconnections among intricate machinery and technology within a networked framework. Nevertheless, the utilization of these measurement devices and set-ups presents notable technological obstacles due to their customary operation in isolation within controlled laboratory environments.

Moreover, it is imperative to note that the proper functioning and longevity of instruments necessitate the expertise of proficient operators. Additionally, the accurate and efficient processing of data also demands the proficiency and skill set possessed by these operators. The initial stride is taken by means of the advancement of 'point-of-care' devices predicated on conventional laboratory instrumentation. The term "point-of-care" in the realm of healthcare pertains to the utilization of benchtop apparatus that does not necessitate stringent laboratory conditions and can be routinely functioned by individuals who have received training, albeit not necessarily possessing advanced expertise. The successful implementation of this endeavor necessitates the reduction in size of the instruments, the development of resilient methodologies, the creation of user interfaces that are streamlined, the automation of processes, the establishment of intrinsic calibration and quality control mechanisms, and the integration of data analyzing and reporting functionalities.

The ultimate phase entails the implementation of completely transportable, optimally compact equipment that is seamlessly integrated with the sensor platform and capable of facilitating on-site operations instantaneously. The formidable technological attempts of developing portable devices endowed with measurement capabilities akin to those of conventional laboratory machinery is of considerable magnitude. Nevertheless, the potential benefits would commensurate, given that such an endeavor would yield a mobile sensor network with the capacity to acquire data from any designated spatial and temporal coordinates.(Roux et al., 2022)

The contemporary mobile smart phones present a compelling technological framework for mobile sensors within a wireless network, due to their inherent capacity to acquire temporal and spatial data and facilitate seamless data transmission, alongside their optimized interface that enables users to engage in a diverse array of activities. The utilization of mobile phone cameras as spectral analyzers has been documented in contemporary research for the purpose of chemical analysis pertaining to potassium(García et al.) and chlorine.(Sumriddetchkajorn et al.) Additionally, these cameras have been employed for the recognition of amplified DNA(Lee et al.) The iSPEX project serves as a remarkable illustration of the immense capabilities inherent in smartphone sensor networks, particularly in the context of monitoring and mapping atmospheric aerosols.

The scientific insights and advances possess significant potential for application within the field of forensic science, particularly in scenarios characterized by a high caseload and constrained forensic interpretation resources. The criminal justice system exhibits a notable inclination towards expeditiously disseminating forensic information, driven by a robust intrinsic motivation. This impetus stems from the recognition that such prompt availability of forensic data serves to facilitate crime resolution and enhance the efficiency of legal proceedings.(Lee et al.)

In order to mitigate the inherent postpones associated with the transportation and analysis of evidence at forensic laboratories, there exists a vested interest within the law enforcement community to engage in on-site and in-house forensic analyses at the location of the crime. Nevertheless, the absence of meticulously controlled laboratory situations, stringent quality control protocols, and comprehensive forensic expertise typically hinders the utilization of these findings as admissible evidence within the court of law.

Given the preliminary nature of the findings, it is imperative to conduct further examination at the forensic laboratory in order to ascertain their veracity and draw conclusive inferences. Moreover, the disorganized compilation of forensic data results in diminished levels of forensic supervision and comprehension. The resolution of these challenges could be addressed, thereby enabling the complete realization of the potential inherent in point-of-care and mobile forensic analyses, through the establishment of an integrated forensic network that facilitates the operation of measurement devices. By leveraging the capabilities of network infrastructure, it becomes feasible to implement essential calibration and quality control protocols, thereby facilitating the effective utilization of forensic instrumentation for generating reliable findings that can be directly employed as evidentiary material.

The proposed network would facilitate the evaluation of data produced in non-forensic laboratory settings by forensic experts, enabling them to offer immediate support and guidance to on-site operators. The activities shed light on the necessity of conducting a more comprehensive subsequent examination at the forensic laboratory for certain samples. The utilization of the forensic expert's capacity is thereby optimized, resulting in enhanced effectiveness, while the generated findings can be seamlessly integrated into the platform, thereby establishing a perpetual cycle of platform refinement and data advancement.

The proposed methodology entails the integration of centralized data collection, which facilitates the acquisition of forensic intelligence and knowledge management, with decentralized forensic analysis that is characterized by its expeditiousness and efficacy. The present proposition, despite its inherent technological complexities, possesses the potential to engender a paradigm shift in the operational efficiency and effectiveness of the forensic information acquisition procedure.

The potential consequences of this development extend to the realm of forensic institutes and experts within the criminal justice system, wherein a paradigm shift may occur. Specifically, this shift would entail a redefinition of the role played by forensic institutes and laboratories, transforming them into custodians responsible for overseeing the maintenance and utilization of forensic platforms, as well as the management of point-of-care and portable equipment and methodologies. Additionally, the implementation of this technology would facilitate the advancement of forensic institutes in the development of highly sophisticated forensic intelligence tools.

These devices would serve the purpose of unveiling potential correlations between cases and evidence, enhancing comprehension of criminal behaviors, monitoring and optimizing law enforcement practices, streamlining the efficacy of forensic investigations, and aiding in the mitigation and disruption of criminal actions.(international 2006.)

14. Chronological Establishment of State Forensic Science Laboratories in India(Project 39A — FSIR.)

Name of States	**Location of the Laboratory**	**Year of Establishment**
Maharashtra	Mumbai	1958
Rajasthan	Jaipur	1959

Tamil Nadu	Chennai	1959
Bihar	Patna	1960
Kerala	Trivandrum	1961
Assam	Guwahati	1963
Jammu & Kashmir	Jammu, Srinagar	1963
Madhya Pradesh	Sagar	1964
Uttar Pradesh	Lucknow	1964
Maharashtra	Bombay	1967
Karnataka	Bangalore	1968
Orissa	Bhubaneshwar	1969
Haryana	Madhuban, Karnal	1970
Himachal Pradesh	Junga	1971
Andhra Pradesh	Hyderabad	1974
Gujarat	Gandhinagar	1974
Punjab	Chandigarh	1976
Nagaland	Dimapur	1982
Meghalaya	Shillong	1987
Manipur	Pangei near Imphal	1989
Delhi	Rohini	1994
Tripura	Agartala	2002
Chattisgarh	Raipur	2002
Andaman and Nicobar Island	Port Blair	2003
Arunachal Pradesh	Banderdeva	2004
Uttarakhand	Dehradun	2006
Jharkhand	Ranchi	2008
Goa	Verna	2008

Central Forensic Science Laboratory	Calcutta	1957
Central Forensic Science Laboratory	Hyderabad	1966
Central Forensic Science Laboratory	Delhi	1968
Central Forensic Science Laboratory	Chandigarh	1978
Central Forensic Science Laboratory	Guwahati	2013
Central Forensic Science Laboratory	Pune	2013
Central Forensic Science Laboratory	Bhopal	2013

15. Crime Statistics: Crimes over the years 1981-1921

Crime is a multifaceted phenomenon that arises from a multitude of intricate factors. The etiology of criminal behavior can be attributed to the multifaceted interplay of social procedures and frameworks. The commission of criminal acts can be attributed to the practice of socialization, which fails to cultivate a robust moral compass within individuals. Concurrently, the incessant growth of desires serves as a potent catalyst, compelling individuals to engage in criminal behavior to satisfy these innate needs.

The causes of criminal behavior can be discerned through a complex interaction of diverse social, financial, socioeconomic, regional, and organizational determinants. Moreover, it is imperative to note that these social variables, in conjunction with various concealed and associated factors, exhibit substantial variations across diverse areas, states, and cultures. The disparities in procedural approaches across

expansive geographical regions, as well as the inherent distinctions in organizational functioning, give rise to considerable divergences.(National Crime Records Bureau (Ministry of Home Affairs)

S.No.	Year	Total IPC Crimes			S.No.	Year	Total IPC Crimes		
		Crime Incidence	Crime Rate	Charge sheeting Rate			Crime Incidence	Crime Rate	Charge sheeting Rate
1	1981	1385757	200.8	61.3	22	2002	1780330	169.5	80.0
2	1982	1353904	192.0	65.3	23	2003	1716120	160.7	80.1
3	1983	1349866	187.4	67.3	24	2004	1832015	168.8	79.8
4	1984	1358660	184.7	67.9	25	2005	1822602	165.3	80.7
5	1985	1384731	184.4	70.2	26	2006	1878293	167.7	80.6
6	1986	1405835	183.5	71.1	27	2007	1989673	175.1	80.1
7	1987	1406992	180.1	72.4	28	2008	2093379	181.5	79.8
8	1988	1440356	180.8	70.7	29	2009	2121345	181.4	78.4
9	1989	1529844	188.5	72.3	30	2010	2224831	187.6	79.1
10	1990	1604449	194.0	70.2	31	2011	2325575	192.2	78.8
11	1991	1678375	197.5	71.3	32	2012	2387188	196.7	78.8
12	1992	1689341	194.7	72.2	33	2013	2647722	215.5	79.5
13	1993	1629936	184.4	72.5	34	2014	2851563	229.2	79.6

14	1994	1635251	181.7	74.1	35	2015	2949400	234.2	77.7
15	1995	1695696	185.1	74.3	36	2016	2975711	233.6	72.9
16	1996	1709576	183.4	76.9	37	2017	3062579	237.7	70.7
17	1997	1719820	180.0	77.5	38	2018	3132955	236.7	68.1
18	1998	1778815	183.2	77.8	39	2019	3225597	241.2	67.2
19	1999	1764629	178.9	78.0	40	2020	4254356	314.3	75.8
20	2000	1771084	176.7	78.4	41	2021	3663360	268.0	72.3
21	2001	1769308	172.3	78.6					

Reported Crime in India- 2021

In the year 2021, a comprehensive tally of 60,96,310 cognizable offences was recorded, encompassing 36,63,360 violations falling under the purview of the Indian Penal Code 1860 and an additional 24,32,950 infractions categorized as Special & Local Laws (SLL) transgressions.(National Crime Records Bureau (Ministry of Home Affairs)

15.1. Crimes Against the Human Body

A comprehensive analysis reveals that a noteworthy figure of 11,00,425 instances of offences that have a direct impact on the human body were officially recorded during the year 2021. This category of crimes constituted a significant proportion, precisely 30.0%, of the overall crimes as per the Indian Penal Code 1860. Among these offences, it is worth noting that the highest number of cases, specifically 5,85,774 cases, were attributed to the offence of causing hurt, which accounts for a substantial 53.2% of the total cases. Following this, cases involving the act of

causing death by negligence amounted to 1,46,195 cases, constituting 13.3% of the total.

Lastly, cases pertaining to the act of Kidnapping & Abduction accounted for 1,01,707 cases, representing 9.2% of the total cases.(National Crime Records Bureau (Ministry of Home Affair) The data pertaining to cases filed under offences against the human body reveals a notable rise of 5.1% in the year 2021 when compared to the preceding year of 2020, which recorded a total of 1,047,216 cases. Furthermore, the crime rate has exhibited an upward trend, escalating from 77.4 in 2020 to 80.5 in 2021.(National Crime Records Bureau (Ministry of Home Affairs).

15.2. Murder

In the year 2021, a comprehensive tally of 29,272 instances of culpable homicide was officially recorded, indicating a slight upturn of 0.3% in comparison to the preceding year of 2020, which documented 29,193 cases.(National Crime Records Bureau (Ministry of Home Affairs)

15.3. Kidnapping and Abduction

In the year 2021, a notable surge in the incidence of kidnapping and abduction was observed, with a total of 1,01,707 cases being officially registered. This figure represents a significant rise of 19.9% when compared to the preceding year, wherein 84,805 cases were reported.(National Crime Records Bureau (Ministry of Home Affairs)

In the year 2021, a comprehensive count of 104,149 individuals (comprising 17,605 males, 86,543 females, and 1 transgender individual) was documented as victims of kidnapping or abduction. Among this cohort, 69,014 individuals (consisting of 10,956 males and 58,058 females) were identified as children, while the remaining 35,135 individuals (comprising 6,649 males, 28,485 females, and 1 transgender individual) were classified as adults.(National Crime Records Bureau (Ministry of Home Affairs)

15.4. Crime against Women

In the year 2021, there was a notable surge in the number of registered cases pertaining to crimes against women, amounting to a total of 428,278 instances. This figure represents a discernible escalation of 15.3% when compared to the preceding year, specifically 2020, wherein 371,503 cases were reported.(National Crime Records Bureau (Ministry of Home Affairs)

The preponderance of instances pertaining to criminal offences targeting women as per the Indian Penal Code1860 were primarily classified under the category of 'Cruelty by Husband or His Relatives', accounting for a significant proportion of 31.8%. Subsequently, cases involving 'Assault on Women with Intent to Outrage her Modesty' constituted 20.8% of the total, while incidents of 'Kidnapping & Abduction of Women' accounted for 17.6%. Lastly, the category of 'Rape' constituted 7.4% of the overall cases reported. The recorded incidence of criminal activity per one hundred thousand female individuals stands at 64.5 in the year 2021, as opposed to the figure of 56.5 recorded in the preceding year of 2020.(National Crime Records Bureau (Ministry of Home Affairs.)

15.5. Crime against Children

In the year 2021, a comprehensive analysis of reported incidents reveals a notable surge in the number of registered cases pertaining to crimes against children. Specifically, a total of 149,404 instances were documented, indicating a significant escalation of 16.2% in comparison to the preceding year's figures, which stood at 128,531 cases.(National Crime Records Bureau (Ministry of Home Affairs).

In terms of percentages, the prominent categories of criminal activities falling under the umbrella of "Crime Against Children" in the year 2020 were Kidnapping & Abduction, accounting for 45.0% of the cases, and offences related to the Protection of Children from Sexual Offences Act, 2012, encompassing child rape, which constituted 38.1% of the reported incidents. The recorded crime rate per 100,000

children in the population is 33.6 in the year 2021, as opposed to 28.9 in the year 2020.(National Crime Records Bureau (Ministry of Home Affairs).

16. **Disposal of Cases by Police and Courts with the aid of Forensic Laboratories in the year 2021**(National Crime Records Bureau (Ministry of Home Affairs).

S. No.	Crime Head under IPC	Total Cases for Investigation	Cases Charge sheeted	Charge sheeting Rate	Total Cases Convicted	Conviction Rate
1	Murder	51,540	26,382	83.8	4,304	42.4
2	Rape	46,127	26,164	80.4	3,368	28.6
3	Kidnapping and Abduction	1,72,302	38,141	36.8	2,665	29.3
4	Rioting	75,937	41,422	87.1	2,964	21.9
5	Hurt (including acid attack)	8,22,384	5,26,994	88.3	54,707	37.1

The table provided illustrates the resolution of cases by law enforcement and judicial systems with the assistance of forensic laboratories during the year 2021. The table presents the different offences recorded under the Indian Penal Code 1860 during a one-year period. 51,540 murder cases were investigated, and charge sheets were filed against 26,382 cases. The total conviction for the offence of murder was 4304. In regard to the investigation of rape cases, a total of 46,127 cases were looked into. Out of these, charge sheets were filed against 26,164 cases. The number of convictions made in these cases amounted to 3,368. The number of reported cases for the offence of kidnapping and abduction was 1,72,302, with 38,141 cases being charge sheeted. A total of 2,665 cases resulted in convictions. A

total of 75,937 cases of rioting were registered. A chargesheet has been filed for a total of 41,422 cases. A grand total of 2,964 convictions were made.The total number of cases investigated for hurt, including acid attacks, was 8,22,384. Out of these cases, charge sheets were filed against 5,26,994. The overall conviction rate stood at 37.1%.

Forensic science has perennially served as a potent, compelling, and significant tool within the realm of justice administration. The comprehensive functionality of the criminal justice system necessitates the indispensable incorporation and active engagement of forensic science. Upon the occurrence of a criminal act, when the initial officer assigned to the case arrives at the scene of the crime, their primary objective is to establish a state of security within the crime scene premises.

This is undertaken with the intention of safeguarding any potential evidence that may be situated within the confines of the crime scene, thereby preventing its compromise or destruction.(Taroni et al.) The commencement of the inquiry into the locus delicti commences with the meticulous exploration of the premises wherein the criminal act transpired, commonly referred to as the crime scene. Subsequently, the diligent retrieval and safeguarding of pertinent evidentiary material ensues, culminating in the transmission of said preserved evidence to the forensic science laboratory for meticulous examination and analysis by a qualified forensic expert.(Coldwell et al.)

The entirety of this evidence, commencing with the acquisition, identification, safeguarding, and transfer of tangible evidence, necessitates the meticulous attention and prudence of the investigating officer. This is due to the direct repercussions on the evidentiary proof to be proffered by the expert in the court, should the physical evidence be compromised or rendered inoperable.

17.Landmark Judgements and the Application of Forensic Science

During examining the charges of extortion, the Petitioner, who holds the position of Managing Director at Power TV, had their username and password for various social media and digital sites, such as Facebook and YouTube, maintained by the agency that was investigating. Additionally, the agency proceeded to seize the television channel equipment belonging to the Petitioner. The Court made an observation regarding the practice of investigating agencies retaining the username and password of social media/digital platforms.

The individuals in question possess the capability to procure the necessary data from said accounts, subsequently necessitating the restitution of altered authentication information to the rightful proprietor of the social media platform. In relation to the search and seizure of items such as servers, computers, and the like, the court has determined that said items shall be restored to the individual from whom they were confiscated subsequent to the extraction of samples.

In the hypothetical scenario wherein cloning becomes a viable technological feat, it is postulated that the resultant clones of said items shall be allocated to the individual in question, while the authentic originals shall be retained by the investigating agency for their purposes. (Rakesh Shetty v. State of Karnataka (2020)

In one of the leading cases (Virendra Khannna v. State of Karnataka (2021) the mobile phone belonging to the Petitioner was confiscated during his period of detainment, with the intention of utilizing it for the purpose of interrogating him regarding a prior criminal matter. The individual in question was requested to disclose his cell phone and email account passwords considering an ongoing inquiry. As per the assertions made by the prosecution, he declined to comply with this request, persisting in his refusal even subsequent to a Court-issued directive to assist. The Petitioner, in contrast, asserted that he had indeed disclosed his passwords in accordance with the given instructions.

Upon a request submitted by the Central Crime Branch (CCB), the Special Court issued approval for the Petitioner to undergo a Polygraph Test due to their failure

to disclose the passwords in question. The Petitioner's opportunity to present a defense in relation to this application was denied, and their consent to undergo the Polygraph test was not obtained. Furthermore, their request for recall was likewise rejected. The Petitioner has raised an objection asserting that the utilization of the polygraph test contravenes the Petitioner's entitlement to protection against self-incrimination. Furthermore, the act of compelling the Petitioner to disclose his passwords is argued to constitute testimonial compulsion, thereby infringing upon his right to privacy as well as his right to maintain silence.

The Court, in its ruling, determined that it lacks the authority to independently initiate the directive for the accused to disclose their passwords, passcodes, and biometric information for the purpose of investigation. The jurisdiction of the tribunal is limited to cases wherein an application has been submitted by one or both involved parties. The Court rendered a decision affirming that the mere acquisition of data derived from a smartphone and/or email account does not inherently establish the culpability of the defendant, necessitating its substantiation throughout the proceedings of the trial. The provision, namely section 311-A of the Code of Criminal Procedure 1973 (Code of Criminal Procedure 1973, s. 311 A), encompasses a significance that surpasses the mere categorization of a sample or signature. The Court further established that a mandate to disclose the password, passcode, or biometrics does not constitute testimonial compulsion or self-incrimination, as it merely constitutes data that must be substantiated by both parties during the course of the trial.

According to the pronouncement rendered in this judicial decision, the Court opined that the utilization of data in the course of a probe would not constitute an infringement upon the entitlement to privacy, but rather would fall within the purview of the exceptions delineated in the Puttaswamy judgement. (Justice K.S. Putaswamy v. Union of India 2017)

In *Fakhruddin v. The State of Madhya Pradesh*, (Fakhruddin v. State of Madhya Pradesh, AIR 1967 SC 1326) the individual in question has been found guilty of engaging in criminal conspiracy, forgery, cheating, and personation. The presiding judge, in accordance with the principles of jurisprudence, deemed it appropriate to admit and accord weight to the testimony of a qualified expert in the field of handwriting analysis. It was observed that when an expert provides an assessment, it is incumbent upon the Court, with the expert's guidance, to independently determine whether it is plausible to assert that two documents were authored by the same individual.

Within the present framework, the Supreme Court undertook an examination of the legal aspects pertaining to the admissibility and evaluation of handwritten evidence. This assertion posits that the Court is not obligated to assume the role of an expert, yet it retains the prerogative to acknowledge a fact as substantiated solely after conducting its own scrutiny and ascertaining the reliability of the views, whether it emanates from an expert or any other witness. In the present instance, the Court arrived at the determination that the contentious writings exhibit such a conspicuous congruence in authorship that the discerning eye can discern this fact without necessitating the assistance of an expert. The indictment was upheld by the Supreme Court.

The present case (Murari La v. State of Madhya Pradesh 1980 SCC 704) concerns a homicide investigation wherein a handwritten document was recovered from the quarters of the deceased, which suggests that the perpetration of the crime was executed by individuals who are disheartened and lacking employment opportunities subsequent to their graduation. According to the expert's assessment, there was a concurrence between the handwritten note and the sample of writing provided by the Appellant.

During the process of scrutinizing the legal framework pertaining to expert evidence, the court initially made the astute observation that the expert in question

should not be regarded as a co-conspirator. The aforementioned observation highlights the potential risk associated with placing undue reliance on the viewpoints of experts. It is crucial to acknowledge that the fallibility of human judgement, rather than the inherent unreliability of experts themselves, is the primary concern.

Experts, despite their specialized knowledge and expertise, are susceptible to committing errors due to various factors such as flawed observations, erroneous assumptions, or genuine mistakes in drawing conclusions. In acknowledging the positive correlation between the level of development and refinement of a scientific discipline and the diminished likelihood of erroneous viewpoints, the Court astutely pointed out that the field of handwriting verification, in comparison to fingerprint analysis, does not exhibit a commensurate degree of infallibility. It has been elucidated that the viewpoint of a graphology specialist cannot be dismissed as an immutable principle, and it has been determined that judicial bodies must demand significant verification in all instances, even if the viewpoint is supported by the most sound and logical justifications.

The responsibility of a proficient individual lies in providing the essential scientific criteria to assess the veracity of their findings, thereby facilitating the judge in forming an autonomous judgement. In the realm of judicial proceedings, it is imperative for courts to exercise prudence and circumspection when evaluating the testimony of a handwriting expert, thereby necessitating a thorough examination of the underlying rationale supporting said expert's opinion. The indictment of the Appellant was affirmed by the Court on the grounds that his handwriting exhibited some correspondence with the note discovered on the table of the deceased individual.

In *Mukesh and Another v. State (NCT of Delhi) and others* (Mukesh and Another v. State NCT of Delhi and Others 2017) appellants were duly found guilty by the court of law and subsequently incarcerated to the ultimate penalty of death. This grave

judgement was rendered in light of their involvement in the heinous acts of gangrape and murder perpetrated against the prosecutrix. In addition to a multitude of corroborating evidence, the prosecution heavily relied upon the utilization of DNA evidence in order to secure the conviction of the appellants. In the process of affirming the verdict and punishment, the Supreme Court engaged in a comprehensive examination of the significance of DNA evidence.

The Court observed that India, akin to numerous other nations, is progressively placing greater reliance on DNA evidence. The significance of such evidence is underscored by its reference to sections 53 A (Code of Criminal Procedure 1973,s 53 A) and 164 A (Code of Criminal Procedure 1973, s 164 A) of the Code of criminal procedure 1973, which pertain to the interrogation of individuals accused of rape and victims of rape, respectively. This serves to establish that DNA profiling has now become an integral component of the legal framework. Upon careful examination of multiple precedents, the court has reached the conclusion that a DNA report should be deemed admissible unless it is unequivocally discredited. In the event that the DNA report is deemed invalid, it is imperative to ascertain the absence of both quality control and quality assurance measures. The acceptance of a DNA report is contingent upon the absence of sampling errors and any indications of sample manipulation.

In *Santosh Kumar Singh v. State through CBI* (Santosh Kumar Singh v. State through CBI 2010 9 SCC 747) the appellant was found guilty of the heinous crimes of rape and murder. The Trial Court, in its discernment, rendered a verdict of acquittal for the accused, thereby dismissing the DNA report and other corroborating evidence. The High Court, in its decision, overturned the determinations made by the Trial Court, encompassing those pertaining to DNA evidence, and subsequently imposed capital punishment upon the defendant. The indictment was upheld by the Supreme Court; however, the death sentence was subsequently reduced to life imprisonment.

During the discourse pertaining to DNA evidence, The Court rendered a decision affirming that a judge lacks the prerogative to supplant their own subjective viewpoint with that of an expert, especially within the realm of a scientific discipline such as DNA profiling. According to the assertions put forth by two esteemed scientists, it has been posited that the genetic material derived from the seminal fluid residues found on the undergarments of the deceased individual, as well as the samples obtained from the swabs and slides, emanated from a solitary origin, specifically attributed to the individual under scrutiny. The Trial Court's assessment, predicated upon extensive consultation of numerous authoritative textbooks, yielded unfavorable conclusions regarding the veracity of the DNA examination, while simultaneously neglecting to duly acknowledge the intricate and technical aspects inherent to the subject matter.

The Trial Court's decision to dismiss the DNA report lacks justification, as no discernible grounds were presented to discredit the two experts responsible for its submission. Consequently, the Court acknowledged the scientific accuracy and precision of the DNA report, deeming it an exemplar of exactitude within the realm of scientific inquiry.

In *Anil v. State of Maharashtra* (Anil v. State of Maharashtra 2014 4 SCC 69.) the appellant stands allegedly accused of engaging in carnal intercourse with a minor male and subsequently causing his demise through strangulation. The individual in question was found guilty and consequently sentenced to death by the Trial Court, a decision that was afterwards upheld by the High Court. In light of the Supreme Court's decision, it is noteworthy to mention that the indictment was duly upheld. However, it is pertinent to highlight that the capital punishment initially imposed was commuted to life imprisonment, specifically entailing a duration of thirty years, devoid of any possibility for remission.

The individual possessing expertise in this particular instance, an Assistant Chemical Analyzer, has conveyed that she has undertaken a pair of DNA

examinations, specifically STR and Y-STR profiling. The Court acknowledged the scientific validity of both tests and found no reason to question the expertise of the expert involved. Henceforth, the admissibility of the DNA test report, which revealed that the deceased was forced in sexual activities was established. The Court further opined that in the majority of cases, when there is a concurrence between the DNA profile of a sample discovered at the location of the criminal incident and the DNA profile of the individual under suspicion, it is typically indicative of a shared biological source for both samples. The validity and reliability of a DNA profile are contingent upon the meticulous implementation of quality control measures and adherence to rigorous laboratory protocols, as the potential for variance in specific outcomes can be influenced by these factors.

In *Pattu Rajan v. State of Tamil Nadu* (Pattu Rajan v. State of Tamil Nadu 2019 4 SCC 771) the appellant stands as the convicted party in a case of culpable homicide that does not meet the threshold for murder. The identification of the murdered individual's body was achieved through the utilization of the superimposition method, whereby the image of the retrieved skull was overlaid onto the photograph of the deceased individual. Upon the initiation of the appeal process, the esteemed High Court, after careful deliberation, maintained the defendant's conviction and, in a notable alteration, revised the charges to the more severe offence of murder.

In the appellate proceedings before the Supreme Court, the appellant has raised a multitude of challenges against his indictment, encompassing, among others, the contention that the utilization of the superimposition technique, rather than the more advanced DNA profiling methodology, was employed in the identification of the deceased individual. The sentence was upheld by the Supreme Court.

During the course of deliberating the contention surrounding the lack of DNA profiling, the Court restated the fundamental responsibility of an expert witness to aid the Court by providing a comprehensive report grounded in their specialized knowledge, accompanied by justifications. This facilitates the Court in forming an

autonomous judgement by evaluating said materials. Nevertheless, it is imperative to acknowledge that opinion evidence holds a merely advisory nature, thereby signifying that the Court is not legally obligated to adhere to expert testimony.

The Court additionally observed that although the precision of DNA evidence is on the rise, it cannot be deemed unequivocally flawless. Hence, the lack of DNA evidence would not engender an unfavorable presumption, particularly in light of the existence of other compelling and trustworthy evidence.

18. Concluding Remarks

The prospective trajectory ought to be imbued with a sense of aspiration, diverging from the present state of affairs that centres its attention on organizational intricacies, technical minutiae, and procedural frameworks. Of paramount importance is the establishment of a universally embraced comprehension of forensic science and its underlying principles. The aforementioned principles ought to serve as a guiding framework for the development and implementation of educational, training, research, and operational practices.

In addition, it is imperative to cultivate a cultural milieu within the realm of forensic science that prioritizes objective and principles over a predominantly technological orientation.(Roux, Willis, et al.) One crucial aspect to consider is the prioritization of educating forensic experts primarily as scientists rather than technicians. Additionally, it is vital to guarantee that even specialized forensic scientists possess a solid grounding in the generalist approach to the field of forensic science.

It is evident that the field of forensic science has been confronted with the persistent challenge of ambiguity, which is anticipated to remain an enduring aspect of this discipline. In light of the recommended definition and the seven principles, it is evident that a newfound sense of guidance has emerged in the realm of managing unpredictability. The multifaceted character of the underpinnings of forensic science, specifically pertaining to the identification and analysis of traces, mandates

the utilization of scientific methodologies from the inception of every inquiry, commencing at the crime scene, and persisting throughout the entirety of the forensic science continuum, employing judicious and cogent reasoning.

The significance of context cannot be overstated, as it is intrinsically linked to the imperative of conducting oneself in an ethical manner, characterized by fairness, openness, and autonomy. It is imperative to recognize and consider alternative perspectives; however, it is crucial to prioritize and vigorously advocate for scientifically substantiated propositions. The present discourse recognizes and acknowledges the prevailing and escalating heterogeneity of forensic science applications, along with their consequential influence in effectively tackling wider societal concerns.(Roux et al., 2022)

The elucidation and foundational tenets that ought to undergird the praxis of forensic science. It is imperative to recognize and endorse the utilization of scientific principles and methodologies as the bedrock of forensic science, while also arriving at a consensus regarding the fundamental nature of the 'trace'. The definition and principles ought to be employed in a comprehensive manner to serve as the foundational framework for informing and guiding the development of forensic science expertise on a universal scale. The competencies, in turn, should serve as a foundation for informing the development of education and training initiatives as well as quality administration programs. The inclusion of concurred skills is imperative to comprehensively tackle the multifaceted nature of forensic science.

It is essential that these competencies encompass both the operational and logical dimensions of the discipline. Furthermore, it is crucial to acknowledge that competencies alone are insufficient; they must be accompanied by a robust framework that encompasses education, instruction, and standard management. By adopting such a holistic approach, we can effectively address the entirety of the forensic science process, from start to finish. It is imperative to incorporate this

cognitive process within the context of the crime scene, throughout the phases of evaluation and interpretation, as well as in the formulation and dissemination of interpretations and beliefs.(Roux et al., 2022)

CHAPTER V

APPLICATION OF FORENSIC SCIENCE IN ADMINISTRATION OF CRIMINAL JUSTICE SYSTEM IN INDIA.

1. Introduction

In the context of criminal cases, it is the jurors who assume the role of fact finders. In order to ascertain the veracity of said facts, individuals are provided with evidentiary support derived from witness testimonies pertaining to the observations or auditory experiences of said witnesses. The determination of whether the testimony establishes, either explicitly or indirectly, with a high degree of certainty that the accused individual is guilty of the offence for which they stand accused, falls within the purview of the jury. Moreover, it is noteworthy that the jury possesses the prerogative to receive testimonies from individuals who are deemed to possess expertise in the subject matter, thereby enabling them to present their conclusions and opinions derived from the findings.(Shelton, 2010a)

Individuals of such standing are precluded from providing testimonial statements regarding the ultimate determination of the defendant's culpability or innocence. The individuals in question possess the capacity to provide their subjective viewpoints, commonly referred to as opinion testimony, in instances where such opinions would prove beneficial to the jury's deliberation in arriving at the ultimate matter at hand. The admissible testimony is confined to subject matters that transcend the ordinary or prevalent encounters of jurors, and wherein the expertise of an expert is deemed necessary to facilitate the jury's comprehension of the significance of the factual evidence presented before it. The quintessential

manifestation of expert testimony lies in the form of scientific experts' testimonies.(Shelton, 2010)

The proof presented in the field of forensic science is derived from the astute observations and expert opinions of individuals who have undergone rigorous training. Its purpose is to assist the jury in comprehending the significance or implications that can be inferred from the factual evidence at hand.(Shelton, 2010) The expert is capable of providing testimony regarding the occurrence of a specific event, the identification of the individual responsible for the event, or the manner in which the event transpired. The subjects of inquiry in this study encompass the fundamental questions pertaining to the identification of individuals, the determination of their existence, and the elucidation of the mechanisms involved. These inquiries are explored through an analysis of diverse scientific evidence. The determination of the perpetrator is a focal point within various domains, including but not limited to deoxyribonucleic acid (DNA), fingerprint, handwriting, hair, and bite-mark evaluation.(Shelton, 2010)

The inquiry pertaining to the manner in which an event transpired is frequently examined within various domains, including tool-mark analysis, weapon and bullet comparisons, explosion, fire, and arson testimony, as well as bloodstain pattern examination. The inquiry pertaining to the occurrence of an event stands as a fundamental facet within the realm of social science expertise. The expeditious advancement of nascent scientific methodologies, particularly the enhanced comprehension of deoxyribonucleic acid (DNA), has exerted and will unquestionably persist in exerting a profoundly remarkable influence on the forensic evidence employed within the framework of the justice system, specifically at the trial stage. The profound implications of these novel scientific innovations have been most prominently observed within the realm of forensic applications, particularly in the context of criminal trial proceedings.

2. The Evolution of Forensic Scientific Evidence and Its Development

The quest for scientific elucidation of enduring human inquiries that captivated the entire world during the 19th and 20th centuries was expansively applied to various facets of vivid society, encompassing the realm of criminal justice.(Shelton, 2010) The judicial system has granted permission for individuals with specialized knowledge, commonly referred to as "experts," to provide their professional advice on matters that were earlier within the sole purview of the jury. These matters include the recognition of individuals through the analysis of fingerprints, as well as the elucidation of intricate specifics pertaining to death or injury through the presentation of medical testimony. The escalation in the utilization and exploration of scientific knowledge has concomitantly led to a proliferation of purported areas of expertise, as well as advancements in the realm of technological developments that have been harnessed or originated to facilitate their practical application.(Shelton, 2010)

Initially, courts demonstrated a certain degree of hesitancy in embracing the purported expertise presented in certain domains, such as the field of handwriting analysis, due to its lack of scientific foundation. Nevertheless, over time, judicial bodies have developed a consistent tendency to readily admit expert witnesses presented by the prosecution, with the intention of assisting the jury in determining the defendant's culpability. The courts exhibited a notable tendency to demand minimal, if not entirely absent, scientific substantiation from the prosecution in relation to the testimonial evidence. The empirical foundation and scientific validity of forensic science evidence produced by the prosecution were seldom subjected to any significant challenges in terms of defense.(Shelton, 2010)

The prosecution presented expert testimony predicated upon the findings of criminal investigators, a significant proportion of whom possessed limited or negligible scientific acumen. In conjunction with the utilization of fingerprints, judicial bodies have permitted the admission of identification testimony as a means to ascertain the identity of individuals, thereby addressing the fundamental query of "who." This practice relies upon the experiential knowledge and presumed

proficiency of witnesses specialized in various domains, including but not limited to handwriting analysis, microscopic hair examination, blood analysis, and bite-mark analysis.(Shelton, 2010)

The results articulated within such testimony were infrequently expressed in terms of probability. Not only was the mentioned testimony duly accepted, but it is noteworthy that these esteemed experts were frequently granted the opportunity to provide testimony asserting that the alleged crime scene or associated item - whether it be fingerprints, hair, writing, bite marks, or any other residual evidence discovered by investigators - exhibited a definitive "match" with a corresponding item from the defendant. Furthermore, these experts were permitted to assert that said match was indeed unique, thereby establishing the defendant as the sole individual capable of producing the crime scene item.(Shelton, 2010)

Testimony from proficient individuals in diverse scientific disciplines was permitted to expound upon inferences concerning the provenance of materials employed in the perpetration of a criminal act, specifically addressing the inquiry of "how." The objective was to establish a connection between said materials and analogous items within the possession of the defendant.

The utilization of comparison microscope evaluation served as the foundation for providing testimonial evidence regarding the congruence between scene bullets and test bullets in terms of their origin from a common firearm. Furthermore, this technique facilitated the determination of whether a specific screwdriver or other implement was employed to produce the distinctive marks observed at the scene.(Shelton, 2010) Additionally, it enabled the establishment of a potential link between the lead composition of a bullet found at the scene and a batch of bullets associated with the defendant. Furthermore, it was observed that certain researchers were granted the privilege of providing testimonies of opinion pertaining to the genesis or modus operandi of occurrences transpiring within a crime scene, specifically addressing the query of "how." The experts expressed their

perspectives pertaining to matters such as the origin of a fire, drawing upon remnants that had withstood the destructive forces of said fire. Additionally, they engaged in the process of reconstructing the intricacies surrounding the infliction of an injury, relying on their meticulous examination of bloodstain patterns present at the location or on the person accused.(Shelton, 2010)

The widespread embrace of expert testimony in the field of forensics has transcended the boundaries of physical sciences and physical examinations. The prosecutor introduced social science testimony, which differs from physical evidence, with the intention of reinforcing the government's assertion regarding the occurrence of a purported act of sexual assault. This testimony primarily addressed the question of "whether" the act had indeed taken place. The courts have granted permission for professionals in the fields of psychology, sociology, social work, counselling, and law enforcement to provide their expert analysis regarding the congruity between a complainant's testimony or behavior and that of other individuals who have experienced similar forms of abuse as described by the complainant. The evident objective of that testimony, irrespective of any instructional constraint imposed by the judge, was not solely to establish the occurrence of the asserted abuse, but rather to affirm the veracity of the victim's account of the manner in which it transpired.(Shelton, 2010) On the opposite extremity of this continuum, it is worth noting that judicial bodies were, nevertheless, disallowing the inclusion of social scientists, presented by the defense, who sought to provide expert testimony regarding the inherent fallibility of eyewitness accounts. This prohibition extended to both a broad assessment of the inaccuracy of such testimonies, as well as an examination of their specific applicability to circumstances resembling those present at the location where an alleged criminal incident occurred.(Shelton, 2010)

Certain advancements in the field of forensic science and technology have been specifically devised with the intention of facilitating their application in the realm of criminal justice inquiry and judicial resolution. Fingerprint and firearm

assessments serve as exemplary illustrations. Additional forensic evidence has its origins in the scientific and technical domains, with a particular emphasis on medicine. Subsequently, these advancements have been unexpectedly applied within the realm of criminal justice. Blood typing and DNA are two apparent instances.(Shelton, 2010)

The utilization of fingerprint comparison as a form of evidentiary support in legal proceedings has garnered acceptance and recognition for a considerable span of time, surpassing the threshold of one century. The initial phase of visual analysis was succeeded by a diverse array of methodologies aimed at the detection and augmentation of prints, as well as the identification of comparable prints through the utilization of a computerized database. The comparative analysis of handwriting specimens represents a seminal form of forensic evidence that has been employed since antiquity.(Shelton, 2010)

The inception of DNA profiling can be traced back to its initial application as a means of ascertaining fatherhood. The initial application of deoxyribonucleic acid (DNA) in a triumphant criminal prosecution within the United States can be traced back to the pivotal case of *Andrews v. State*. (Andrews v. State, 533 So. 2d 841 Fla. Dist. Ct. App. 1988) Subsequently, the acceptance of DNA evidence in the context of a criminal proceeding was initially sanctioned by a state supreme court in the notable case of *State v. Woodall*. (State v. Woodall 385 S.E.2d 253 W. Va. 1989) The admission of DNA evidence, which has been appropriately collected and subjected to rigorous analysis, has become a standard practice across all jurisdictions. Undoubtedly, DNA stands as an unequivocal testament to its status as the paramount forensic science advancement of the twentieth century. DNA has emerged as the preeminent form of forensic scientific evidence, commonly referred to as the "gold standard." Its use in DNA typing has garnered widespread acceptance and is regarded as the benchmark against which numerous other forensic individualization methodologies are evaluated.(Shelton, 2010)

The emergence and subsequent prominence of DNA as a paramount form of forensic scientific evidence has exerted a profound influence on various other types of scientific evidence.

The use of DNA testing possesses a notable capacity, under appropriate conditions, to furnish definitive exculpatory evidence subsequent to a conviction, particularly in cases where biological samples were not subjected to testing during the trial proceedings. The postconviction efficacy of DNA examination can be attributed to the identical characteristics inherent in the technology that have rendered it highly advantageous throughout the course of inquiry and trial proceedings. The enduring nature of DNA allows for the dependable examination of genetic material even years following the occurrence, while the variability in DNA sequence systems significantly enhances the likelihood of obtaining a definitive exculpatory outcome.

The advent of forensic DNA evidence has undeniably presented a significant advancement in the realm of science and technology. However, it has inadvertently engendered a consequence wherein conventional forms of forensic scientific evidence, hitherto deemed dependable and widely acknowledged by trial judges, have come under scrutiny due to the introduction of these novel scientific evaluations. The advent of novel scientific methodologies has prompted certain judicial bodies to reevaluate the soundness of various forensic techniques, including serology testing, comparative bullet lead analysis, bite-mark identification, handwriting analysis, hair and fibre analysis, as well as tool-mark and ballistics testimony.(Shelton, 2010)

In *Tommy Lee Andrews v. State of Florida* (Tommy Lee Andrews v. State of Florida, 533 So 2d 841 1988) the aggrieved in question was roused from her slumber by the culprit as he exerted pressure upon her physical form, accompanied by the sensation of an object, reminiscent of a straight-edged razor, being applied in close proximity to her neck. The perpetrator, whom the victim was only able to identify during the trial as an individual possessing physical strength and belonging to the African

diaspora, forcefully covered her oral cavity, instructed her to maintain silence, and issued a menacing ultimatum of fatality should she happen to catch a glimpse of his countenance. The victim engaged in a physical altercation with the intruder, resulting in lacerations inflicted upon her facial region, neck, lower extremities, and feet as a consequence of her resistance. Subsequently, the perpetrator proceeded to engage in non-consensual vaginal penetration with the individual in question. After this act, the perpetrator absconded with the victim's handbag, which contained an approximate sum of $40, before vacating the premises.

The post-assault medical checkup conducted subsequent to the incident was duly informed to the law enforcement authorities, wherein it was ascertained that the victim's vaginal region exhibited the presence of seminal fluid. The state proffered DNA print identification evidence that establishes a connection between the appellant and the criminal act in question. The DNA analysis entailed a comparative examination of the appellant's DNA composition, as derived from his blood sample, with the DNA composition extracted from both the victim's blood sample and the vaginal swab obtained from the victim near the assault.

The trial court's exercise of discretion in admitting the findings from the test in this case was not found to be abusive. In stark juxtaposition to the evidentiary findings procured through hypnosis, truth serum administration, and polygraph examinations, the evidentiary findings derived from DNA print identification manifest a foundation rooted in well-established scientific standards.

3. A Preliminary Exploration into the Admissibility of Expert Scientific Opinion

The comprehensive and systematic procedures involved in the investigatory and legal domains, commencing from the initial detection of a criminal act to the final pronouncement of judgement by the court, are fundamentally designed to ascertain the accurate identification of the culpable individual and to absolve those who are proven to be innocent. Nevertheless, it is important to acknowledge that in

numerous instances, the intricacy inherent in both aforesaid processes, as well as the multifaceted nature of the inputs made to the discourse, can give rise to obstacles and complications that hinder and deflect the progression of both scientific and legal contentions. Consequently, these impediments may ultimately result in an outcome that fails to meet the desired level of satisfaction.(C. Adam, 2016)

The notion of relevance has long been codified in legal systems worldwide, yet in recent years, a discourse has arisen concerning broader facets of the introduction of scientific evidence in court proceedings and the responsibilities of scientists acting as expert witnesses. There exist numerous rationales for this phenomenon, encompassing notable progressions in scientific methodologies, the imperative for investigators to grapple with increasingly intricate and prominent criminal cases, the escalating focus on these issues, and the continuous reactions of the legal community and legislators to such occurrences.

In accordance with legal provisions, an expert witness is granted the opportunity to furnish the court with evidentiary contributions encompassing both factual and opinion-based elements. In the realm of jurisprudence, it is incumbent upon the presiding judge to exercise their authority in determining the admissibility of any evidence that pertains to the subject matter under deliberation. Nevertheless, it is imperative to acknowledge the existence of certain variations in rules and practices, a phenomenon predominantly influenced by case law. In numerous jurisdictions, the evolution of legal principles is primarily propelled by the issuance of landmark judgements by appellate courts, which serve to elucidate specific legal issues. Consequently, these judicial precedents subsequently govern and impact the cases that follow.

The manner in which the legal framework pertaining to the management of scientific evidence within the judicial system has undergone a process of development, and is currently undergoing further evolution, characterized by

modifications to the legislation on a domestic scale, as well as other pertinent initiatives undertaken by governmental bodies and organizations.(C. Adam, 2016)

In the preceding three decades, the focal point of apprehensions pertaining to scientific evidence within the judicial realm has revolved around three primary concerns:

1. **Can the presented evidence be deemed admissible by the court of law?**

The concept of admissibility encompasses the determination of whether the presented evidence holds relevance to the legal discourse, thereby possessing inherent value in contributing to the resolution of the matter at hand commonly referred to as probative value. Additionally, admissibility is contingent upon an array of supplementary considerations, including the standing of the expert witness, the calibre of the employed methodology, and the foundational scientific principles upon which the evidence is based.

The determination of admissibility lies within the purview of the presiding judge and is characterized by a categorical nature, as it pertains to the binary outcome of either permitting or disallowing the expert witness from presenting their testimony. According to certain legal authorities, it has been posited that the judge assumes the role of a "gatekeeper" with regards to expert evidence. The determination made by the presiding judge regarding the admissibility of evidence, as well as the rationale underlying such a determination, holds paramount significance within the realm of the legal system.(C. Adam, 2016)

2. **Can the veracity of the evidence be deemed trustworthy and dependable?**

The notion of reliability, while potentially influential in determining admissibility, is inherently intricate and subject to substantial heterogeneity in its treatment among different legal systems and jurisdictions. At a rudimentary level, the court is obliged to evaluate the legitimacy of the scientific methodology employed and

ascertain whether the expert's assessment is firmly grounded in the outcomes of their research. Nevertheless, the degree to which this phenomenon contributes to the acceptance of evidence or whether validity may alternatively serve as a determining factor in assessing the legal significance of said evidence remains a subject of ongoing scholarly discourse. Hence, the paramount consideration lies in the extent of dependability rather than the mere categorization of evidence as reliable or unreliable.

3. **Has the assessment of the evidentiary significance been conducted in a thorough and comprehensive manner, subsequently conveyed to, and comprehended by, the court?**

The scientist bears the onus of formulating and executing experimental measurements, subsequently scrutinizing the outcomes, and eventually extrapolating their implications within the given context and conditions. Nevertheless, in the capacity of an expert witness, it is imperative to expound upon the elucidation of this piece in order to effectively convey its significance to the court, thereby enabling the judge, the jury, and the legal professionals to comprehensively grasp its relevance within the context of their deliberations. The degree to which this objective may be attained, and the methodology employed exhibit significant variations among the various subfields within the realm of forensic science, as well as among individual practitioners and within the legal systems and jurisdictions. (C. Adam, 2016)The emergence of a heightened magnitude surrounding the discussion over the admissibility, reliability, and quality of scientific opinion in the courts in recent times can be attributed to several factors. It is important to acknowledge that expert evidence has been presented in legal proceedings for approximately two centuries. However, the contemporary context has witnessed a surge in the scrutiny and deliberation surrounding these matters.

Firstly, advancements in scientific knowledge and technology have significantly expanded the scope and complexity of expert evidence. The rapid pace of scientific

progress has led to the emergence of new fields of study and specialized areas of expertise. Consequently, the courts are increasingly confronted with scientific opinions that delve into intricate and nuanced subjects. This expansion of scientific inquiry has necessitated a more rigorous examination of the admissibility and reliability of expert evidence. Secondly, the evolving legal landscape has placed a greater emphasis on the importance of scientific evidence. (C. Adam, 2016)

Courts are now more inclined to rely on scientific opinions to inform their decision-making processes. This shift reflects a growing recognition of the value that scientific expertise brings to the resolution of legal disputes. Consequently, the stakes associated with the admissibility and reliability of scientific opinion have been raised, leading to intensified debates in recent times. Furthermore, the increased public awareness and scrutiny of legal proceedings have contributed to the intensification of the debate. The advent of the internet and social media platforms has facilitated the dissemination of information and fostered a more engaged and informed public. As a result, legal cases involving scientific evidence are subject to heightened public scrutiny, leading to a greater demand for transparency, accountability, and the assurance of scientific rigor. Lastly, the inherent limitations and challenges associated with scientific evidence have become more apparent in recent times. The recognition of potential biases, conflicts of interest, and limitations in the reproducibility of scientific findings has prompted a critical examination.(C. Adam, 2016)

During the mid-Victorian era, it was not uncommon for legal proceedings to witness the juxtaposition of scientific expert witnesses, who would engage in intellectual discourse within the confines of the courtroom. The exhibition of conflicting experts in the public sphere has been observed to have a detrimental impact on the perceived objectivity of scientific endeavors, as well as on the impartiality of the scientists involved in the pursuit of truth. The situation experienced a certain degree of mitigation during the initial phase of the twentieth century, as a result of the

formalization of forensic science and the centralization of considerable expertise within regional and national laboratories.

The temporal shift in the situation commenced during the 1970s, wherein a surge of disapproval towards "junk science" emerged, predominantly within the United States. This disapproval was primarily directed towards scientists who were perceived to be swayed by the vested interests of large corporations that had employed them. Additionally, the persisting occurrence of wrongful convictions further accentuated the perception of forensic science and forensic scientists as substantial contributors to this predicament.(C. Adam, 2016) Commencing this discourse with instances wherein the legal process has unequivocally deteriorated and instances of miscarriages of justice have transpired proves to be both expedient and enlightening.

While it is important to acknowledge that the causes of such events are multifaceted and cannot be attributed to a singular factor, it is evident that the emergence of DNA profiling has played a pivotal role in uncovering and shedding light on these occurrences.

4. Reliability, Admissibility and Scientific Evidence

The common law system strives to promote the equitable resolution of cases within a legal framework that is susceptible to evolution through the establishment of legal precedents. Within the framework of this particular system, the establishment and potential evolution of legal principles are contingent upon court decisions, thereby giving rise to a judicial precedent that necessitates acknowledgment in subsequent legal discourse.(Edmond, 2012b)

The absence of a statutory legal framework established by parliament is not considered a complete lack thereof; rather, it signifies that the construction of said laws is subject to judicial examination, which may subsequently establish legal precedents that hold equal weight to the original statutes. The process by which

legal norms are established and enforced is intricately intertwined with the interpretation thereof. The legislative provisions pertaining to evidentiary matters are inherently susceptible to the same procedural dynamics.

The crux of the matter lies in the differentiation between expert testimony, which pertains to opinion evidence, and alternative manifestations of witness evidence. According to the principles of common law, witnesses are restricted to the provision of factual information exclusively when presenting their statements within the judicial setting. It is imperative for them to refrain from articulating any form of subjective judgement or personal viewpoint, particularly with regard to their observations or auditory experiences.(Kiely et al., 2006) Conversely, it is imperative to acknowledge that the deposition of an expert witness may encompass a combination of factual and opinion-based evidence; nevertheless, it is crucial for such evidence to maintain its pertinence to the subject matter being deliberated upon. The delineation of an expert is contingent upon a multitude of factors and is subject to ongoing scholarly discourse. Scholars have posited various criteria and frameworks to ascertain the defining characteristics of an expert. Expert witnesses occupy a highly esteemed position wherein they possess the unique ability to furnish the jury with opinion-based evidence pertaining to subjects within their specialized domain, which typically surpasses the comprehension and familiarity of most jurors.(Commission, 2011)

Consequently, this serves as the foundational premise upon which the court's determination to admit said evidence is predicated. But the court may have to decide what kind of knowledge a witness has, how much of it they have, and how relevant it is. Also, expert evidence may be questioned at different levels, which brings up new problems that the court has to solve. In this context, the primary function of the judge may ultimately entail assuming the responsibilities of a discerning arbiter charged with determining the admissibility of expert opinions, thereby serving as a metaphorical 'gatekeeper'.(Moriarty et al., 2005)

When deliberating on the admissibility of expert testimony, the presiding judge must take into account a multitude of interconnected and frequently intricate factors. Nevertheless, it is imperative to narrow down these factors to two key aspects: namely, relevance and reliability. The concept of relevance pertains to the evidentiary value that allows the jury, in their capacity as the fact-finder, to reach a final determination regarding the resolution of the case. Nevertheless, it is imperative to acknowledge that pertinent evidence may be omitted from consideration if its potential advantage to the court is surpassed by the perilous possibility that it could result in unfair prejudice, disorientation, or serious postponements in the court processes.

Given that expert opinion lies beyond the purview of widespread understanding within the legal domain, it becomes imperative to ascertain its reliability. Failure to do so would render the judge, jury, and counsel incapable of discerning the validity and accuracy of the testimony at hand. The examination of the foundation of reliability and the subsequent determination of its indispensability as an essential requirement for admissibility, or alternatively, its role in influencing the assessment of evidentiary weight, constitutes a prominent subject of deliberation within the judicial sphere.

In the realm of scientific expert evidence, although there exists a prevailing presumption of inherent reliability, it is noteworthy that numerous instances have arisen wherein the veracity of such testimonies has been subject to scrutiny. This is particularly evident in situations where the scientific knowledge at hand is either pioneering or lacks established foundations. As a result, a series of established cases have been determined, which have exerted a significant influence on subsequent discussions and deliberations.

In recent times, there has been a notable surge in discourse surrounding the concept of admissibility, resulting in consequential judicial decisions being rendered in numerous jurisdictions. It is of particular interest to note that a significant number

of seminal cases that have contributed to the establishment of legal standards for the admissibility of evidence have predominantly emerged from the realm of civil litigation. Notably, these cases have primarily revolved around matters pertaining to health and safety, as well as medical concerns. The occurrence of instances in which professionals provided testimonies within the primary subdisciplines that constitute the fundamental framework of forensic science is relatively limited. However, it is worth noting that several such instances can be observed within the peripheral domains of this field. However, it is important to note that the ramifications of these legal decisions have ultimately extended to encompass all forms of forensic expert evidence, in addition to expert evidence in a broader sense.

5. Admissibility Test in the United States

In conjunction with the district, state, and federal courts, the United States possesses a dual-tier framework of appellate courts, operating both at the state and federal levels, wherein each state is equipped with a supreme court alongside the US Federal Supreme Court serving as the ultimate adjudicator. Certain cases have the potential to transition between these various courts, thereby necessitating ongoing deliberation regarding the admissibility of evidence within this judicial framework. (Federal Rules of Evidence 2015 USA)

The United States has been actively engaged in examining the legal standards and procedures pertaining to the acceptability of expert scientific evidence within the judicial system for nearly a century, commencing with the landmark Frye decision in 1923. (Frye v. United States 293 F 1013 DC Cir 1923) Preceding said date, the judicial system in the United States adhered to a customary approach akin to that observed in the United Kingdom, whereby the admission of evidence was contingent upon the perceived proficiency of the testifying individual. During the judicial proceedings pertaining to the case of James Frye, who stood accused of the homicide of Dr. Robert Brown, a proficient witness was summoned to testify. This witness had employed the technique of assessing systolic blood pressure as a

purported means of detecting deception exhibited by the accused. The focal point of concern in this context did not revolve around the proficiency possessed by the witness. Rather, it centered on the extent to which the identification of sudden fluctuations in blood pressure aligned with the veracity of the statements made by the individual, as well as the degree to which this methodology garnered acceptance within the wider scientific society. The defense posited that there exists no verified proof of the efficacy of this technique, a contention which was duly acknowledged and embraced by the court.

The pronouncement established the widely recognized Frye criterion, which stipulates that in order for expert evidence to be deemed admissible in a court of law, it must have attained approval within its respective field of study. The criterion of admissibility, which pertains to the overall acceptability of evidence, serves as a fundamental basis for ensuring the dependability of expert testimony. It is imperative for the court to possess a collective assurance that the scientific viewpoint being presented will not lead to any form of misinformation during its deliberations or adversely influence its judgements.

The criterion, which can be deemed as conservative, was frequently employed with a considerable degree of rigour throughout the 1970s, a period marked by the emergence of numerous novel analytical methodologies. However, it is worth noting that not all states universally embraced this particular standard. The exclusion of forensic evidence was a result of its novelty, which consequently rendered the scientific basis of the testimony inadmissible.

5.1. Conforming to the Frye Criteria

In the month of October in the year 1970, the United States Appeal Court deliberated upon the appeal presented by Orville Stifel, who sought to challenge his sentence for the act of homicide committed against Dan Ronec. (United States v. Stifel, 433 F 2d 431 1970) The crime involved the dispatching of an explosive device via postal means. The prosecution introduced a body of evidence, which

included the findings derived from neutron activation analysis (NAA) conducted on pieces of the detonated bomb, as well as on reference materials procured from the defendant's workplace.

During its inception, the technique known as Neutron Activation Analysis (NAA) emerged as a novel method with the inherent capacity to effectively discern and delineate the intricate nature of substances based on their trace element composition. This viewpoint concurred with the outcomes derived from other well-established methodologies such as microscopy and atomic absorption analysis. Stifel's appeal was predicated upon the novelty inherent in the NAA technique, and he posited that the expert evidence in question should be deemed inadmissible, in accordance with the Frye criterion.

Both parties presented additional expert witnesses to engage in a discourse regarding the acceptance of NAA as a technique within the scientific community. Some made reference to the vast array of research publications that support the methodology, as well as the fact that evidence derived from NAA has been deemed admissible by other judicial bodies in recent times. Consequently, the appellate court dismissed the appeal and affirmed the trial court's decision to admit the findings derived from neutron activation analysis in the present matter.

5.2. The Daubert Test as Admissibility and the Gatekeeper Role

The subsequent advancement in the establishment of the acceptability of scientific evidence emerged, not by means of a criminal trial, but rather as a consequence of civil litigation directed towards a prominent corporate entity. During that particular period, there was a growing prominence of an issue characterized by the perception that certain experts involved in corporate litigation cases exhibited a predisposition towards biased behavior, favoring the parties they represented. Additionally, it was observed that large corporations resorted to employing unsound scientific arguments, commonly referred to as "junk science," as a means to counter legal actions initiated by individuals.

The seminal ruling rendered by the United States Court of Appeals in 1993, known as *Daubert v Merrell Dow*, (Daubert v Merrell Dow Pharmaceuticals Inc, 509 US 579 113 S Ct 2786, 1993) aimed to harmonize and elucidate the stance regarding the permissibility of scientific expert testimony. Merrell Dow Incorporated, a prominent pharmaceutical corporation, was responsible for the production of Bendectin, a pharmacological intervention aimed at mitigating nausea in expectant mothers. However, this drug became the subject of controversy as it was purportedly linked to congenital malformations observed in offspring whose mothers had administered Bendectin during their pregnancies.

The company was faced with a legal challenge in the form of a joint lawsuit filed by two individuals, namely Jason Daubert and Eric Schuller, who sought compensation for the alleged harm they suffered. The company's stance in the court proceedings was that there exists no scientific investigation that conclusively establishes the drug's association with birth defects. Conversely, the legal representatives for the children contended that substantial evidence, derived from studies involving animal cells, live animals, pharmacological research, and a re-evaluation of previously published epidemiological studies, supports the assertion of such a connection. The federal court rendered a judgement that dismissed the case put forth by the plaintiffs, thereby affirming the stance adopted by Merrell Dow. The perspective of the court was that the evidence presented by the petitioners was deemed inadmissible due to its failure to satisfy the Frye criterion. In the judgement, it was claimed that the animal studies and the molecular-based pharmacological research did not and could not prove direct causality, while the re-analysis of previously published data had not been subjected to peer review on its own.

Therefore, confirmation of its reliability was not established. Peer review is a widely recognized and established practice within the scientific community and other domains of expertise. It entails the meticulous examination, comprehension, and validation of scholarly contributions by individuals who possess an in-depth

comprehension of the subject matter. This rigorous process serves to affirm the authenticity and dependability of novel insights, thereby bestowing them with the imprimatur of credibility.

Paradoxically, in the process of substantiating this ruling, which commences by citing a segment of the Frye criterion, the judges proclaimed that the Frye test had indeed been rendered obsolete by the comparatively lenient thresholds for admissibility. While it is important to acknowledge that the concluding statement may be subject to disagreement among scientists, it is noteworthy that these arguments have assumed a significant role subsequent to the widespread acceptance of this ruling by numerous states. In essence, the ruling underscores the significance of both pertinence and dependability in the evaluation of scientific expertise. It places particular attention on the validity of the scientific methodology, while assigning the trial judge the responsibility of determining the admissibility of such evidence.(P. G.-C. L. Rev. 1993.)

The Daubert ruling has superseded the Frye general acceptability rule at the federal level and in slightly more than half of the states within the United States. This replacement is predicated upon the principles of relevance and reliability, wherein the latter is evaluated by means of particular inquiries pertaining to the validity, precision, and acceptability of the methodology and the underlying scientific principles as endorsed by the scientific establishment.

In a more specific vein, the judgement meticulously itemizes the subsequent points that ought to be explicitly explored by the court:(Imwinkelried, 1990)

1. Is the testimony predicated upon scientific methodologies and techniques that have undergone rigorous scrutiny, such as the formulation of pertinent hypotheses followed by experimental scrutiny.
2. Has the procedure undergone rigorous evaluation by experts in the field to assess its validity, and has this evaluation been substantiated through research, as an exemplification?

3. Can the error rate be ascertained for the particular technique employed in the examination of evidence, and were there established protocols followed in the execution of these examinations in this study?
4. To what extent does the scientific community generally accept the methodology and underlying scientific principles employed in this study?

The subsequent utilization of these aforementioned criteria in particular instances soon afterwards to the Daubert ruling has engendered numerous challenges and has become a focal point of extensive deliberation and discourse within the legal and scientific realms, as well as other relevant sources of research and discourse.

5.3. The Daubert Trilogy

In the aftermath of the *Daubert v Merrell Dow* case, the United States witnessed the emergence of two additional legal decisions within the realm of litigation. These rulings, while relatively modest in impact, nonetheless made noteworthy adjustments to the existing criteria governing the admissibility of expert testimony. The collective set of these three judicial decisions has acquired the esteemed designation of the 'Daubert Trilogy'(Bernstein et al.)

In *General Electric v Joiner* (General Electric Company v. Joiner, 522 US 136 1997) Robert Joiner, an individual employed as an electrician at the esteemed General Electric Company, subsequently experienced the unfortunate development of lung cancer. The individual in question posited that his occupational engagement had resulted in his prolonged exposure to a diverse array of chemical substances, most notably polychlorinated biphenyls (PCBs), furans, and dioxins.

Consequently, he contended that this sustained exposure had played a contributory role in the manifestation and progression of the disease. The petitioner's request was bolstered by expert testimony, which provided substantiation that the probable aetiology of his cancer can be attributed to the exposure he endured to said substances. The central matter under consideration by the appellate court pertained

to the question of whether the presiding judge of the district court had failed to employ suitable legal decision-making abilities, thereby engaging in an act of 'abusing his discretion,' by electing not to admit the aforementioned expert evidence. The insufficiency of the association of animal-related studies and four epidemiological studies on the carcinogenic properties of PBCs was contended, as it failed to provide a satisfactory foundation for the expert testimony. This contention was based on the absence of a conclusive link between exposure to PBCs and the development of the illness.

Hence, the ruling in question has raised concerns not only regarding the pertinence of the data, but also regarding its capacity to substantiate the assertions put forth by the expert witness. The ruling primarily centered its attention on the judge's function as a gatekeeper and emphasized the necessity for the judge to possess the capability to engage highly proficient and impartial experts during the pretrial phase. This engagement is intended to seek counsel on intricate matters where determinations regarding admissibility may hinge upon profound comprehension and nuanced contentions.

The Daubert case exclusively pertained to the examination and evaluation of scientific testimony. In the matter of *Kumo Tyre Company Ltd v Patrick Carmichael* (Kumo Tire Company Ltd v. Patrick Carmichael, 119 S Ct 1167 1999), it is noteworthy that the expert witness retained by Mr. Carmichael possessed specialized knowledge in the field of tyre failure examination. This expert witness, in alignment with Mr. Carmichael's position, provided testimony asserting that the unfortunate occurrence of a fatal blowout to one of Mr. Carmichael's tyres can be attributed to a flaw arising from the manufacturing process. The Kumo Tyre Company endeavored to challenge the admissibility of the evidence presented by the opposing party, asserting that the approach employed by the latter lacked reliability. The court deliberated on the notion that differentiation could not be established uniformly across the entire range of proficiency, spanning from pioneering scientific knowledge to specialized technical domains such as

engineering, all of which are fundamentally grounded in scientific principles. Hence, it is imperative that the Daubert criteria be employed in the evaluation of this particular case pertaining to the investigation into tyre safety. Moreover, it is incumbent upon the judge to assume the role of a gatekeeper in determining the admissibility of said evidence. Given the court's determination, it was found that the testimony presented in this case lacked substantiation through peer review, exhibited an absence of a discernible error rate, and failed to demonstrate widespread acceptance of the employed approach.

Consequently, the evidence in question was deemed inadmissible. The ruling in question holds considerable significance as it expands the application of the Daubert criteria to encompass all forms of specialist technical evidence, regardless of whether they are derived from empirical scientific knowledge or experiential expertise. In light of these advancements, it is noteworthy to observe that numerous states within the United States have presently elected to abstain from incorporating either one or both of these post-Daubert judgements.

5.4. Hearings Following the Daubert Decision

Following the landmark Daubert ruling, defence attorneys began to regularly mount challenges against forensic testimony, contending that it failed to satisfy the established criteria. In numerous instances, the presiding judge would convene a distinct pre-trial hearing to determine the admissibility of the pertinent expert testimony. The proceedings, commonly referred to as 'Daubert hearings', have assumed a pivotal role in the endeavor to discern the categories of evidence and domains within forensic science that exhibit a comparatively less substantial scientific foundation.(J. M.-F. L. Rev. 2017

Dennis Mooney was convicted of the crimes of robbery, conspiracy, and the utilization or possession of a firearm during the perpetration of a violent offence subsequent to an occurrence in Waterville, Maine during the month of November in the year 2000. (United States v. Dennis Mooney, 315 F 3d 54 2002) A portion of

the incriminating evidence against the individual in question consisted of correspondence addressed to his romantic partner, wherein he explicitly confessed his involvement in the criminal act. However, during the trial proceedings, he vehemently refuted the authenticity of these written confessions, asserting that they were not penned by his own hand.

Preceding the commencement of his trial, Mooney submitted a formal request to preclude the admission of expert testimonies provided by the prosecution pertaining to document and fingerprint examination. This motion was based on the contention that said testimonies failed to satisfy the criteria set forth by the Daubert test. The admissibility of the fingerprint evidence was predicated upon its historical efficacy and judicial scrutiny. Consensus was reached regarding the recognition and reliability of handwriting analysis as an established domain of expertise.

Furthermore, it was acknowledged that the proficiency exhibited in the examination of handwriting evidence has been duly acknowledged within the United States judicial system for a considerable duration, thus affirming its status as a dependable procedure. The motion under consideration encompasses a thorough examination of various cases, wherein the court's stance on permitting experts to delineate both analogous and disparate attributes has been scrutinized. However, it is noteworthy that in certain instances, the court has withheld the prerogative of these experts to proffer their opinions regarding the origin of the handwriting in question. The motion was rejected by the hearing, thus granting permission for the expert witnesses to provide their testimonies. The court supported this ruling by acknowledging that Daubert had no intention of excluding material—for instance, testimony based on tried-and-true methods like handwriting analysis—that could have previously been allowed under Frye.

6. The Principle of Admissibility in the Legal System of England

In the jurisdiction of England and Wales, the fundamentals governing the treatment of expert evidence derive from the body of customary law, commonly referred to

as common law. The courts within this jurisdiction have adopted a relatively lenient and practical stance towards the admissibility of expert evidence, as well as the standards and credentials that delineate an individual as an expert.

Throughout the passage of time, the approach has undergone modifications and enhancements, primarily driven by intermittent pivotal cases that have been subject to appeal. It is noteworthy to mention that the courts have not encountered any significant alterations or objections in relation to this approach. The presence of inconsistencies observed in numerous rulings has regrettably failed to effectively concentrate or elucidate the criteria for admissibility within the confines of this jurisdiction.(Boylan-Kemp, 2014)

Terence Turner was convicted in February 1974 for the act of homicide committed against his romantic partner through the utilization of a blunt instrument, specifically a hammer. (R v. Turner 1975 1 All ER 70) This unfortunate occurrence transpired subsequent to his girlfriend's disclosure, wherein she admitted that he did not possess the biological relationship to the unborn offspring she was carrying. Despite not explicitly acknowledging any psychological disorder, Turner lodged an appeal against a judgement of guilt, relying on the testimony of psychiatric experts. These experts contended that his offence was driven by an overwhelming surge of passion, indicative of the profound emotional bond he shared with the victim. Nevertheless, the presiding judge rendered a verdict deeming the evidence as inadmissible. The rationale behind this decision lies in the court's recognition that matters falling under the purview of "common knowledge and experience" do not necessitate expert testimony or guidance.

The present discourse offers a comprehensive examination of the essence of expert testimony, while also presenting a discerning framework for determining the circumstances under which it may be deemed inadmissible. Furthermore, should the witness possess the ability to effectively persuade the court regarding the calibre of their expertise, as well as its pertinence to the issues currently being deliberated

upon by the court, it shall result in the admission of their testimony. Curiously, notwithstanding the ongoing discourse surrounding the matter of reliability, it appears that the English judicial system perceives it as a subject within the purview of the court to be deliberated upon in relation to the evidentiary value.

Consequently, no specific standards or principles have been deliberated upon or put forth that would establish reliability as a prerequisite for the admission of expert testimony. In recent years, there has been a notable increase in the number of obstacles directed towards the qualifications and areas of expertise of witnesses, particularly those aligned with the defense. These challenges, while relatively minor in nature, have garnered attention within the legal sphere.

In *R v Gilfoyle* (R v. Gilfoyle 2001, 2 Cr App R) the accused was found guilty of the act of homicide, specifically the deliberate killing of his wife who was in an advanced stage of pregnancy, accomplished through the method of hanging. It is worth noting that the medical evidence presented during the trial was characterized by a delicate equilibrium, as it offered no definitive conclusion regarding the nature of the incident, leaving open the possibility that it could have been either a case of murder or suicide. Two appeals were conducted, with the second occurring in 2001 subsequent to a referral from the CCRC.

During this appeal, the defense offered psychological profiling evidence, which was derived from an apparent suicide note and other writings. The purpose of this evidence was to elucidate the mental condition of the deceased individual during the period leading up to her demise. The testimony has been deemed inadmissible. The testimony, which bore resemblance to previous accounts that had been dismissed in other contexts, was once again met with rejection during Gilfoyle's subsequent appeal, ultimately resulting in an unfavorable outcome.

The ruling establishes a set of criteria that can be employed to evaluate the substance of a particular area of expertise, as well as the reasoning employed by an expert in formulating their perspective. These criteria are crucial in determining the

admissibility of such expert testimony. While the explicit mention of reliability is absent, it is evident that the issues delineated in this judgement pertain to the fundamental principles that underlie the testimony and the imperative for the court to comprehend the rationale behind the expert witness's opinion, as substantiated by the identified factual basis.

The appeal in the case of *R v Luttrell* (R v. Luttrell and others, 2004 EWCA Crim 1344) shifts the focus from the admissibility of evidence to the evaluation of its probative value, thereby centering the discussion on the weight of expert opinion. In the year 2003, Gerrard Luttrell, alongside six additional individuals, was convicted at the esteemed Reading Crown Court for the offence of engaging in the act of managing stolen items, the estimated value of which exceeded six million pounds. (R v. Luttrell and others, 2004 EWCA Crim 1344) The appellant lodged an appeal against his sentencing, asserting that the admission of lip-reading evidence derived from CCTV images was inappropriate due to its novelty and unreliability. Alternatively, if the evidence was allowed, the presiding judge should have provided the jury with a cautionary instruction regarding its constraints.

During the initial trial proceedings, a professional and seasoned lip-reader provided expert testimony regarding a discussion involving Luttrell, wherein his involvement in criminal acts was discussed. Nevertheless, upon subjecting the lip-reader's abilities to scrutiny by an additional expert, it was revealed that her accuracy in deciphering words was merely approximate, with a success rate of approximately 50%. Furthermore, two other experts concurred with the notion that evidence derived from closed-circuit television (CCTV) is inherently unreliable.

Notwithstanding this, the presiding judge rendered a ruling affirming the admissibility of the evidence and dismissed a contention positing that the practice of lip-reading lacks a foundation of dependable knowledge or expertise. The appellate court concurred with this perspective and, notably, made reference to the criteria outlined in the Australian Bonython case (1984) (Queen v. Bonython 1984

38 S A S R 45) as delineating the two requisite conditions for admissibility. However, it was further stipulated that the jury would be responsible for evaluating the probative value of said opinion.

The legal representative for Luttrell contended that an additional investigation ought to be administered, with the specific aim of ascertaining its reliability and validity. This necessitates a comprehensive elucidation of the approach to be presented before the court, thereby enabling it to be subjected to rigorous cross-examination. The rejection was based on the premise that lip-reading is a cultivated proficiency or aptitude, rather than a scholarly field of study, and thus conducting tests of this nature would be unsuitable.

The perspective stands in stark contrast to the stance adopted in the United States during the Kumo Tyre case of 1999. (Kumo Tire Company Ltd v. Patrick Carmichael, 119 S Ct 1167 1999) While it is imperative to take into account the matter at hand when determining admissibility, one would anticipate that the reliability factor ought to play a role in shaping the jury's contemplations regarding the evidentiary value in relation to the case. In contrast to the perspective presented in Gilfoyle, (R v. Gilfoyle 2001, 2 Cr App R) it is evident that this particular ruling does not accord reliability the status of a principal determinant in the establishment of admissibility. However, it is important to note that the appellate court did include the recommendation that in instances such as this, the presiding judge should duly inform the jury about the potential constraints associated with lip-reading or comparable forms of evidence.

It is crucial to acknowledge that even expert testimony in this domain may not always guarantee complete accuracy. The perspective held by the appellate court was that, during the initial trial, the jury was adequately apprised of the constraints pertaining to the case of Luttrell, thereby leading to the dismissal of his appeal. This particular case serves as an illustration of the court's potential acceptance of expert testimony that is acknowledged to possess inherent unreliability. However, it is

crucial to note how the judges must be duly apprised of the specific characteristics of this unreliability.

Subsequently, the jury is empowered to consider this information when assessing the significance to be attributed to the evidence in question.

When contemplating the somewhat elusive method of psychological profiling, it becomes relevant to juxtapose the perspective of this particular court on lip-reading with that of the court in the Gilfoyle case. The determination of admissibility in relation to the area of expertise is undoubtedly a matter that warrants careful examination. However, the concerns pertaining to reliability are typically entrusted to the jury, who must grapple with such matters during their deliberations on the evidentiary weight laid out before them.(L. B.-A. J. of P. Science 1977.)

7. Admissibility Test in India

The field of forensic science assumes a pivotal function within the framework of India's criminal justice system. The primary objective of the legal system in any given nation is to ensure the administration of justice. To accomplish this goal, it is imperative for the courts to effectively identify the perpetrator, thereby safeguarding the legal entitlements of the aggrieved. Forensic science would undoubtedly prove to be of substantial assistance to the criminal justice system.(Rsch. 2023.) The genesis of forensic science can be traced back to antiquity, wherein the inaugural instance of an autopsy was conducted on none other than Julius Caesar.

In antiquated India and the nations of the Middle East, a rudimentary manifestation of veracity assessment or a comparable analogue to the polygraph examination was historically conducted with the aim of ascertaining the culpability of the person charged. Prominent figures in the medical and scientific community, such as Sir William James Herschel, Henry Faulds, Francis Galton, and Sir Edward Richard Henry, have made substantial contributions to the advancement of forensic

methodologies that find application in contemporary times. India has also borne witness to the establishment of various investigating departments and bureaus dedicated to the pursuit of forensic inquiries across multiple states. In contemporary times, a plethora of technological advancements have been witnessed in the realm of forensic science on a global scale, including the Indian Evidence Act 1872 (now the Bharatiya Sakshya Adhiniyan 2023) context.

These advancements encompass a wide array of approaches such as Hair Bacteria Assessment, DNA phenotyping, 3D Photography technology, forensic palynology, alternative light photography, and various others.(Rsch. 2023.) The criminal statutes of India encompass numerous provisions that substantiate the significance of forensic evidence, thereby highlighting its profound effectiveness within India's legal framework.

In the Indian Evidence Act 1872 (now the Bharatiya Sakshya Adhiniyan 2023) context, it has come to light that numerous instances have emerged wherein the judiciary has effectively employed forensic evidence to substantiate legal claims. It is noteworthy that the Criminal Procedure Identification Bill of 2022 serves to substantially augment the significance of such evidence within the legal framework.

7.1. The Evolution and Progression of Forensic Science in India

In the Indian Evidence Act 1872 (now the Bharatiya Sakshya Adhiniyan 2023), context, it is noteworthy that the evaluation of fingerprints, footprints, document analysis, and chemical tests were conducted under the purview of the State Criminal Investigation Department (CID). The establishment of forensic science testing facilities by several state governments, with the inaugural laboratory being established in Calcutta in 1952, marked a significant development in the field. The Bureau of Police Research and Development currently serves as the primary organization for the Central Government. Subsequently, additional establishments developed to facilitate the pursuit of investigative endeavors, such as the

department specializing in the study of explosives, as well as the esteemed the 2023 Security Press.(Tewari et al..) The Centre for DNA fingerprinting and diagnostics, situated in Hyderabad, undertakes a comprehensive range of activities encompassing DNA profiling, testing, assessment, and bioinformatics.(Tewari et al.)

7.2. The Growth and Development of Forensic Science in India

The enumeration of multiple agencies and bureaus entrusted with the task of carrying out diverse forensic inquiries in the Indian Evidence Act 1872 (Bharatiya Sakshya Adhiniyan 2023) context can be delineated as follows:

1. The Anthropometry Bureau, which was founded in 1892 in Calcutta, serves as a repository for criminal records, encompassing photographic documentation and comprehensive descriptions of physical attributes.
2. In accordance with the principles set forth by William Herschel, Edward Henry proceeded to set up a fingerprint bureau in Calcutta in the year 1897. This bureau was dedicated to the meticulous recording of fingerprints belonging to individuals of criminal disposition.
3. The establishment of the Department of Explosives took place in several prominent cities, namely Nagpur, Calcutta, Bombay, Madras, Agra, and Gwalior.
4. The testing of human blood and seminal stains in criminal investigations has become imperative in specific instances, as indicated by the serologist appointed by the Government of India. The Institute of Serology was officially founded in the city of Calcutta in the year 1910 and has since played a pivotal role in the resolution of numerous criminal investigations.
5. The inception of the Footprint and Forgery division within the Criminal Investigation Department (CID) dates back to the year 1915, when it was founded in the city of Calcutta. The primary objective of this division was to systematically gather, safeguard, and scrutinize the footprints left behind

by individuals under suspicion. In the year 1917, the regional government of West Bengal took the initiative to set up the Forgery Department under the purview of the Criminal Investigation Department (CID) with the primary objective of investigating and resolving a multitude of forgery cases.

6. The Ballistics Department, which was founded in Calcutta in the year 1930, assumed the crucial responsibility of scrutinizing firearms. Subsequently, numerous state forensic laboratories incorporated the ballistics division into their existing infrastructure.(Tewari et al..)
7. In India, it is noteworthy that mobile forensic laboratories have been established in numerous states across the nation. The laboratory facilitates the efforts of law enforcement agencies in the examination of a crime scene by providing them with the means to effectively identify, gather, and safeguard crucial pieces of evidence. In addition, these entities offer a service that enables the acquisition of visual documentation through the medium of photography, thereby facilitating the preservation and documentation of the crime scene as well as any pertinent and substantial evidence.

7.3. Forensic Science and Emerging Technologies

In contemporary times, the pervasive advancement of technology has engendered a concomitant integration of its applications across diverse domains, including the field of forensic science. Consequently, even practitioners within this discipline have not remained aloof from harnessing technological tools to facilitate the identification and examination of criminal activities. Crime inquiry is currently witnessing the widespread utilization of sophisticated processes and devices on a global scale. This discourse aims to provide a succinct overview of the contemporary technologies employed by forensic experts worldwide, including their application within the Indian Evidence Act 1872 (now Bharatiya Sakshya Adhiniyan 2023) context.

1. The Evaluation of Hair Microbiota: In instances where individuals have engaged in sexual intercourse, whether mutual or non-consensual, the microbial composition within their respective hair samples becomes intermingled. Consequently, if a resemblance is identified in the microbial communities present in the hair samples of both the aggrieved and the alleged perpetrator, it becomes feasible to ascertain the identity of the offender in criminal investigations. (Bhattacharyya., 2020)
2. DNA phenotyping is a scientific approach employed by forensic experts to integrate genomics and computational capabilities in order to generate a visual representation, akin to a police sketch, of an individual based solely on a solitary DNA sample obtained from the scene of a criminal incident. The utilization of computational systems can facilitate the generation of trait probabilities through the process of decoding deoxyribonucleic acid (DNA). With the utilization of this technological advancement, it becomes feasible to predict attributes such as sex, hair color, eye color, and height with a commendable level of accuracy, reaching up to 90% efficacy. (Bhattacharyya., 2020) The utilization of 3D photography technology facilitates the experts in employing image layering techniques to aid investigators in the comprehensive analysis of the underlying factors contributing to criminal activities, as well as the modus operandi employed. Consequently, this contributes to the accumulation of a more robust body of evidence that can be presented before the court. (Bhattacharyya., 2020) Forensic palynology, a discipline within the field of forensic science, involves the utilization of fossilized pollen grains to detect and investigate criminal activities. The remarkable resilience of pollen grains enables them to endure significant fluctuations in temperature, rendering them impervious to adverse environmental conditions. Moreover, these microscopic particles have the ability to traverse the human digestive system without undergoing any discernible alteration. Consequently,

Pollens can be subjected to analysis through the employment of computational tools and DNA analysis techniques, more specifically referred to as DNA metabarcoding. (Bhattacharyya., 2020)

3. alternative light photography, which entails the application of a specialized camera that employs blue light and orange effects to scrutinize subcutaneous bruising. (Bhattacharyya., 2020)
4. Additionally, forensic experts employ a variety of dry testing methods, including but not limited to color testing, ultraviolet spectrophotometry, and microcrystalline testing, to ascertain the existence of unknown compounds. (Bhattacharyya., 2020)
5. The use of link analysis software is imperative in the investigation of potential financial fraud. This specialized software enables forensic experts to meticulously examine the financial transactions of individuals, thereby facilitating the determination of any fraudulent activities that may have transpired. (Bhattacharyya., 2020)
6. The technique of Automated Fingerprint Identification (AFI) involves the application of specialized software to compare an accurately obtained fingerprint with a wide digital database containing fingerprints of numerous individuals. Once a suitable match is identified, this method enables forensic scientists to effectively identify and analyze fingerprints. The utilization of cutting-edge techniques in latent print analysis within the field of forensic science includes the employment of the Integrated Automatic Fingerprint Identification System (IAFIS) and Micro X Ray Fluorescence (MXRF). The numerical value provided by the user is. (Bhattacharyya., 2020)
7. The use of computer-based techniques for facial reconstruction serves the purpose of inferring the visual characteristics of an individual who has suffered from decomposition or distortion. In such cases, the employment of forensic software enables the input of user data, particularly derived from

the remains of the deteriorated or impaired human body. (Bhattacharyya., 2020)

8. The advent of time tracing fingerprint technology represents a sophisticated approach through which investigators can ascertain the precise moment at which a fingerprint was deposited, thereby facilitating the exclusion of innocent suspects who had vacated the crime scene well in advance of the commission of the offence. The numerical value provided by the user is. (Bhattacharyya., 2020)
9. The determination of the geolocation of an individual of interest, whether they be the perpetrator or a target, can be achieved through the examination of stable isotopes of water. By evaluating the stable isotopes of water contained within a solitary strand of hair obtained from the site of the crime, it becomes possible to ascertain the various locations that said individual has traversed or inhabited. The numerical value provided by the user is. (Bhattacharyya., 2020)

7.4. The Importance of Forensic Science to the Criminal Justice System

Forensic science constitutes a salient facet within the framework of the criminal justice system.

At its core, this discipline pertains to the systematic examination and analysis of scientific and physical evidence procured from the locus delicti. The field of forensic science elucidates the unique features of the individual who perpetrated the criminal act. The available evidence unambiguously delineates the inherent characteristics (what) of the criminal act perpetrated. The factual proof also provides insight into the temporal aspect of the alleged crime.

The forensic evidence substantiates the precise whereabouts of the transgression, namely the crime scene. The forensic examination additionally takes into consideration the modus operandi employed by the perpetrator. Ultimately, one arrives at the culmination of discerning the underlying causation behind the

perpetration of the criminal act. Forensic analysts engage in the process of reconstructing the unique characteristics pertaining to both the perpetrator and the individual who has fallen victim to the crime.(Narejo et al.)

Throughout the entirety of the criminal inquiry procedure, evidence is meticulously collected from the crime scene or obtained through the testimony of an individual who possesses firsthand knowledge of the crime. This evidence is subsequently subjected to rigorous examination within a specialized forensic laboratory setting, after which the findings are ultimately offered within the judicial forum. Each crime scene possesses unique characteristics, rendering it outstanding in its own right, while simultaneously presenting various obstacles that must be addressed.

Forensic science assumes a pivotal function within the framework of the criminal justice system, as it furnishes empirically grounded insights via the meticulous examination of tangible manifestations. By examining physical evidence, such as fingerprints, traces of footprints, blood droplets, hair, mobile devices, and other technological apparatuses, as well as automobiles and weaponry, forensic science endeavors to ascertain the identity of the perpetrator. This phenomenon pertains to the establishment of a connection between the perpetrator of a criminal act and various objects that have been either abandoned by the offender at the location of the incident or retained by the offender subsequent to the event, as well as the victim involved in said incident. ((Forensic Science Strategic Research Plan, 2022-2026. Forensic Science Office of Justice Programs, 2022), 2022)

Conversely, in the event that the retrieved clues fail to prove a connection between the charged person and either the victim or the location of the incident, the exoneration of the accused party is thereby ascertained. Forensic science, in this manner, additionally serves to safeguard the individuals who are unjustly accused. Owing to the advent of DNA technology as a contemporary modality within the realm of forensic science, a copious wealth of data is made available to the investigating personnel, thereby equipping them with the capacity to apprehend the

perpetrator solely on the grounds of scientific proof that has been inadvertently deposited at the scene of the crime.(Narejo et al.)

7.5. Provisions Of Law Pertaining to the Application of Forensic Jurisprudence within the Criminal Justice System of India

The Indian Evidence Act 1872, (now The Bharatiya Sakshya Adhiniyan 2023) encompasses specific provisions delineated in section 45, 46, 51, 60, 159, 65 B, 136 (now sections 33, 61, 62, 63, 45 and section 141) that facilitate the admissibility and application of forensic experts' reports within the judicial realm. In the event that the Court is confronted with the task of rendering a judgement on a matter pertaining to law, science, or art, it is pertinent to note that section 45 of the Indian Evidence Act 1872 (now section 39 of Bharatiya Sakshya Adhiniyan 2023) provides the Court with the authority to admit the opinions of individuals possessing specialized knowledge in said foreign law, science, or art.

This provision also extends to cases involving the determination of handwriting or finger impressions. In a manner akin to the statement, it is vital to note that section 45 of Indian Penal Code 1860 (now 39 of the Bharatiya Sakshya Adhiniyan 2023) delineates a fundamental tenet. This rule stipulates that in instances where the opinion of an expert holds relevance, any fact that may be deemed irrelevant under normal circumstances assumes relevance if it either substantiates or refutes the expert’s conclusion. (The Indian Penal Code, 1860 s. 45.)

Both the Indian Evidence Act 1872 and Code of Criminal Procedure Code 1973 (now Bharatiya Sakshya Adhiniyan 2023, and the Bharatiya Nagarik Suraksha Sanhita, 2023) provide support for the inclusion and utilization of expert evidence within the legal framework. According to section 53 of Code of Criminal Procedure 1973, (now section 51 of the Bharatiya Nagarik Suraksha Sanhita, 2023, in cases where an individual is apprehended on the basis of an alleged crime that is of a nature and has been purportedly carried out under conditions that provide adequate reasons for suspecting that an inspection of the person in question will yield

evidence pertaining to the commission of said crime, it is deemed permissible for a legally authorized medical specialist, acting upon the advice of a police officer holding a rank no lower than that of a sub inspector, as well as any individual working in the best interests and under the guidance of said medical expert, to conduct an examination of the arrested person. This inspection should be essential to determine the pertinent details that may serve as evidence in relation to the aforementioned crime. (The Code of Criminal Procedure 1973, s. 53)

Furthermore, the application of force that is fairly essential for the purpose of conducting such an examination is also sanctioned. According to the stipulations outlined in subsection 2 of Section 53, it is explicitly indicated that in the event that a checkup is to be conducted on an individual of the female gender, said examination must be carried out by a female authorized medical specialist, or alternatively, under the direct supervision and guidance of such an expert. (The Code of Criminal Procedure 1973, s. 53(2))

Section 53(A) of the Code of Criminal Procedure 1973, (now section 52 of the Bharatiya Nagarik Suraksha Sanhita, 2023) confers upon an individual, who has been apprehended on the grounds of perpetrating or endeavoring to perpetrate rape, the right to undergo an examination conducted by a duly enrolled expert in medicine. The primary objective of this examination is to procure pertinent evidence pertaining to the commission of said crime. The duly registered medical specialist is required to compile a comprehensive report detailing the results of their examination. This report must include, among other pertinent details, an explicit account of any discernible bodily marks or injuries present on the accused individual. Additionally, the report should encompass an in-depth explanation of the materials obtained from the accused individual for the purpose of DNA profiling. (The Code of Criminal Procedure 1973, s 53(A))

Section 54 of the Code of Criminal Procedure 1973(now section 53 of the Bharatiya Nagarik Suraksha Sanhita, 2023) pertains to the meticulous examination of an

individual who has been apprehended, as conducted by a medical expert, subsequent to a formal request made by the aforementioned detained individual. According to the said provision, it is stipulated that upon being taken in custody an individual, whether it be during their appearance before a magistrate or at any point during their period of detainment, they possess the right to undergo an examination by a medical specialist, should they so desire. This examination serves the purpose of providing proof that may potentially refute the allegations of their involvement in committing the act of violation. (The Code of Criminal Procedure 1973 s. 54)

Section 174 of the Code of Criminal Procedure 1973, (now section 194 of the Bharatiya Nagarik Suraksha Sanhita, 2023) confers upon the law enforcement agencies the authority to undertake the examination and documentation of cases pertaining to self-inflicted fatalities, alongside other matters of legal significance. According to the provided details, it is stipulated that upon receiving notification, either from the officer in charge of a police station or from another police officer who has been specifically authorized by the state government, regarding an individual's suicide, homicide by another person, death caused by an animal, machinery, or accident, or a death occurring under conditions that reasonably suggest the commission of a crime by another individual, said officer shall promptly notify the closest Executive Magistrate who possesses the authority to conduct inquests.

Subsequently, the officer shall move on to the location where the deceased individual's body is situated. In the presence of at least two reputable individuals from the surrounding community, an inquiry shall be conducted by the officer, who will then compile a report detailing the evident cause of death. This report shall include a description of any injuries, broken bones, bruises, or other visible signs of injury observed on the body, as well as an account of the manner in which these marks appear to have been caused and the equipment or tool responsible for their infliction. (The Code of Criminal Procedure 1973, s. 174)

Section 156 of the Code of Criminal Procedure 1973, (now section 175 of the Bharatiya Nagarik Suraksha Sanhita, 2023) confers upon the Magistrate the authority to conduct inquiries in the event of the demise of an individual while under the custody of law enforcement authorities, or in circumstances falling within the purview of section 155 (3). (The Code of Criminal Procedure 1973, 155(3)) In the eventuality described, the magistrate possesses the authority to conduct an inquiry pertaining to the circumstances surrounding the deceased individual's demise, either as a supplementary measure or as an alternative to the inquiry undertaken by the investigating police officer.

Section 164 A of the Code of Criminal Procedure 1973, (now section 184 of the Bharatiya Nagarik Suraksha Sanhita, 2023) provides for the permissibility of subjecting a rape victim to a medical checkup, which is to be carried out by a duly enrolled medical expert working at a hospital operated by the government or a local authority. In the event that said specialist is unavailable, the examination may be carried out by another duly registered medical specialist, provided that the victim or a representative acting on her behalf grants consent to such an arrangement. The healthcare professional will be responsible for generating a comprehensive report detailing the examination findings. Notably, the report will include a precise account of the biological sample obtained from the female individual for the purpose of DNA profiling, among other pertinent details. (The Code of Criminal Procedure 1973, s. 164 A)

Section 293 of the Code of Criminal Procedure 1973, (now section 329 of the Bharatiya Nagarik Suraksha Sanhita, 2023) confers the authority to employ reports furnished by government scientific experts as admissible evidence in legal proceedings. The said provision provides that a document, which claims to be a report authored by a scientific expert employed by the government, pertaining to a subject matter that has been duly presented to said expert for assessment or analysis, may be admitted as evidence during any form of investigation, legal trial, or other similar proceedings. (The Code of Criminal Procedure 1973, s.293) Subsection 4

unambiguously delineates the roster of esteemed scientific authorities within the governmental domain.

This comprehensive list encompasses individuals such as chemical examiners or assistant chemical examiners serving the government, the esteemed chief inspector of explosives, the deputy director or director or assistant director of a central forensic science laboratory or a state forensic science laboratory, the distinguished serologist to the government, and any other government scientific expert. (Code of Criminal Procedure 1973, s. 293) (now section 329 of the Bharatiya Nagarik Suraksha Sanhita) Forensic Toxicology holds a paramount position within the realm of forensic science. The present study pertains to the examination and evaluation of biological specimens with the objective of ascertaining the existence of toxic substances, encompassing pharmaceutical compounds.

The toxicology report possesses the capacity to furnish crucial insights pertaining to the nature of chemicals detected within an individual, as well as whether the quantity of said substances aligns with a therapeutic dosage or exceeds a detrimental threshold. The findings can be employed for the purpose of drawing logical conclusions when assessing the potential impact of a substance on an individual's mortality, morbidity, or cognitive and physiological impairment.

The Indian Penal Code 1860 has extensively addressed the matter of poisoning through various provisions. For instance, section 272, 273 pertains to the act of adulterating food or drink, (now section 274, 275 of Bharatiya Nyaya Sanhita, 2023) while section 274 focuses on the contamination of drugs. (now section 276 of Bharatiya Nyaya Sanhita, 2023) Additionally, section 275 emphases on the sale of adulterated drugs, (now section 277 of Bharatiya Nyaya Sanhita, 2023) while section 276 outlines the penalties associated with the sale or supplying for sale of any medicinal preparation, drug, or an alternative drug or medicinal preparation (now section 278 of the Bharatiya Nyaya Sanhita, 2023)

Section 278 of the aforementioned legislation imposes penalties upon individuals who, of their own volition, engage in activities that result in the contamination of the surrounding atmosphere to an extent that it becomes detrimental to the well-being and physical condition of individuals. (The Indian Penal Code 1860, s. 278) (now section 280 of the Bharatiya Nyaya Sanhita, 2023, Section 328 of the legal framework delineates the punitive measures applicable to individuals who, with the deliberate intention of engaging in unlawful activities, inflict bodily harm upon another individual through the utilization of poisonous or intoxicating substances. (The Indian Penal Code 1860, s. 284)

The inclusion of fingerprint evidence and the potential involvement of a handwriting expert to determine the authenticity of a signature or handwriting are provisions acknowledged within the Indian Evidence Act 1872 (now Bharatiya Sakshya Adhiniyan 2023). Sections 45 A, 65 A, 65 B, 67 A (now sections 61, 62, 63, 66 of the Bharatiya Sakshya Adhiniyan 2023) of the Indian Evidence Act 1872, delineates the criteria for determining the admissibility of a signature, writing, or seal that has been acknowledged or proven to the court's satisfaction as having been authored or created by a specific individual. This provision allows for a comparison to be made between the signature, writing, or seal and the one that is being presented as evidence, even if the former has not been presented or proven for any other objective. The court possesses the authority to instruct any individual currently in attendance within its premises to transcribe specific words or numerals, thereby facilitating a comparative analysis between the transcriptions and those purportedly executed by said individual. It is pertinent to note that section 45 (now section 39 Bharatiya Sakshya Adhiniyan, 2023) of the relevant legislation extends its applicability to encompass the examination of fingerprint impressions as well. (The Indian Evidence Act 1872 , s. 45) Forensic psychology, as a constituent discipline of the broader field of forensic science, assumes a pivotal role in the discernment of the underlying motivations exhibited by the individual under investigation.

Forensic psychologists play an essential part in assisting law enforcement agencies in their investigative endeavors, while concurrently engaging in extensive research endeavors to furnish the police with pertinent guidance and counsel. Section 45 the Indian Evidence Act 1872 (now Section 39 of the Bharatiya Sakshya Adhiniyan 2023) confers upon the court the authority to solicit the expert opinion in instances where it is necessitated to formulate a conclusion pertaining to matters of foreign law, science, or art, or to ascertain the authenticity of handwriting. It is imperative to note that such a specialist viewpoint must be germane to the matter at hand. Forensic psychologists possess the capacity to effectively convey factual information in order to provide valuable assistance to the judicial system.

7.6. Evidentiary Value of Forensic Findings

Forensic findings are not deemed to possess the status of a definitive evidentiary component, but rather serve as an expert perspective employed for the sake of substantiation. The Indian Evidence Act 1872 (now the Bharatiya Sakshya Adhiniyan 2023) encompasses provisions pertaining to the determination of relevance and admissibility of expert opinions. (The Indian Evidence Act 1872 s. 45) An expert can be defined as an individual who has dedicated a significant amount of time and effort towards the acquisition of knowledge and expertise in a specific field of study. Consequently, experts possess a heightened level of proficiency and competence in the subject matter, rendering them capable of providing informed opinions and insights when called upon to do so.(Gawali et al.) The absence of legally prescribed examinations to ascertain the requisite level of expertise or qualifications for individuals to be recognized as experts is evident.

The acceptance of a witness as an expert may be contingent upon a confluence of factors, including but not limited to the following:

1. Demonstrable expertise, which comprises academic accomplishments, professional training, practical experience within the relevant field,

available resources, and the adept utilization of said resources in order to arrive at a well-founded conclusion.

2. To enhance comprehensibility, it is imperative to prioritize clarity in the presentation of reports. This can be achieved through the deliberate avoidance of technical terminology and the utilization of lucid language. Furthermore, the inclusion of visual aids such as photographs, charts, and sketches, which are substantiated by empirical evidence, can significantly contribute to the layman's appreciation and understanding of the opinion being conveyed.
3. The concept of relevancy encompasses more than a mere presumption of facts. It involves the process of drawing conclusions based on one's own experiential knowledge or from the works of reputable authors that have been published and recognized within the academic community.

The categorization of expert evidence as a form of "opinion evidence" is a well-established principle. It is widely recognized that the opinion of a witness, whether pertaining to a matter of fact or law, is generally deemed insignificant. (Khushboo Enterprises v. Forest Range Officer AIR 1994 SC 120.) The testimony of a witness is limited to the presentation of factual information, devoid of any subjective interpretation or inference regarding the consequences or outcomes of said facts. Furthermore, the witness is restricted to providing evidence solely pertaining to factual occurrences that have been directly observed by their sensory faculties. (Babuli v. State 1973 Cri LJ 510)

The judicial function entails the formation of an independent opinion by the judge with regard to the facts presented.(Gawali et al.) The sole exception to this principle pertains to the viewpoints expressed by witnesses who exhibit specialized skills, akin to those of experts.(Gawali et al.) It is imperative to underscore the significance of acknowledging that the acceptance of an expert's opinion is not predicated solely upon their assertion. The individual in question must demonstrate to the court that his results possess the qualities of impartiality and scientific rigor.

The primary responsibility of the expert witness is to provide the presiding judge with the essential scientific standards required to evaluate the veracity of the inference.

This provision of criteria empowers the judge to exercise their own autonomous judgement by employing said rules. (State v. Madhukar 1967 Cri LJ 167) The admissibility of an expert's findings is contingent upon the expert being subjected to examination as a witness, thereby affording the aggrieved party the chance to engage in cross-examination. Moreover, it is imperative to dismiss any assertion made by an authority figure that lacks substantiation through logical justifications. (State of Himachal Pradesh v. Jai Lal AIR 1999 SC 3318) The acceptance of expert evidence is dependent upon specific criteria, which serve to advance the fundamental principles of justice. The principle that an expert witness helps neither the prosecution nor the defense, but rather provides assistance to the court, should be fervently embraced by experts. In addition, the court should adopt a judicious strategy in its dealings with expert testimony. The proposition posits that the principle mandating the exercise of caution in relying exclusively on expert testimony without substantial corroborative evidence ought to be universally implemented across all legal cases, wherein an expert witness is proffering their testimony. (Haji Mohammad Ekramul Haq v. State of West Bengal AIR 1959 SC 488)

Moreover, it is essential to exercise meticulousness and prudence when considering the testimony provided by an expert. (The Indian Evidence Act 1872, s. 46.) The judicial system has consistently maintained that expert evidence is a form of evidence that possesses inherent limitations, necessitating supplementary corroboration that is both independent and dependable. (Magan Bihari Lal v. State of Punjab 1977 Cri LJ 711) While it is acknowledged that there is no definitive criterion for establishing a conviction exclusively on expert testimony. (S. Gopal Reddy v. State of Andhra Pradesh 1996 Cri LJ 3237) Scholars opine that it would be prudent to refrain from relying just on subjective proof for conviction,

particularly if said evidence lacks logical and scientific substantiation. (Murarilal v. State of M.P. AIR 1980 SC 531)

One of the fundamental principles observed by judicial bodies with respect to expert testimony is the steadfast adherence to maintaining their autonomy, exercising independent judgement, and refraining from relinquishing their free will to the opinions put forth by experts. In every instance wherein expert testimony is presented before the Court, it is incumbent upon the Court to duly consider the weight of such evidence and exercise its discretion in determining the extent to which it is deemed appropriate. Subsequently, the Court must independently form its own judgement pertaining to the matter at hand, which has been elucidated through expert testimony. (State of UP v. Krishna Gopal, 1989 Cri. LJ 288)

In light of the prevailing legal framework in India, it is pertinent to assert that forensic evidence holds the potential to be deemed admissible within the purview of expert opinion. The forensic evidence is accorded equal standing with other scientific or expert evidentiary materials, without any particular emphasis placed upon its importance, with due consideration given to the precision, dependability, and conclusiveness of its discoveries. In the case of *Sabur Hossain Biswas v. State of West Bengal and Ors.* (Sabur Hossain Biswas v. State of West Bengal and Ors. 2008 Cri LJ 1183), the High Court has underscored the notion that even if we presume, purely for the sake of argument, that the DNA test yields advantageous results for the petitioner, it would not exonerate him from the charge under Section 376 of the Indian Penal Code 1860.

This is because the trial Court is obligated to assess the charge based on the evidence provided by the prosecutrix and any other witnesses, if available. If the trial Court deems the proof offered by the prosecutrix and/or any other witnesses to be adequate in establishing that the accused has indeed perpetrated the crime under Section 376 of the IPC, then the outcome of the DNA test alone would hold no significance. If the testimonies provided by the witnesses, including that of the

prosecutrix, are deemed insufficient to prove the petitioner's culpability for the offence of rape, it follows that the outcome of the DNA test, even if it were to confirm the paternity, would hold no significance. Hence, it can be argued that the present scenario does not warrant the conduction of a DNA test.

Section 45 of the Indian Evidence Act 1872, (now section 39 of the The Bharatiya Sakshya Adhiniyan 2023) allows for the admission of forensic proof as expert testimony if the investigating police officer determines that such evidence is necessary to prove the occurrence of a crime. Based on his expertise and understanding of the topic, the expert must persuade the court of his methodology, legitimacy, and the veracity of his conclusions. The court may establish an opinion based on the findings and accept that view if it seems plausible in light of other evidence.

7.7. The Criminal Procedure Identification Act 2022

The Identification of Prisoners Act of 1920 represents a longstanding legislative measure originating from the era of British colonial rule in our nation. This act conferred upon the police the authority to collect pertinent data pertaining to individuals under suspicion, including but not limited to their footprints and fingerprints. In contemporary times, the realm of technology has undergone swift and substantial developments necessitating the revision of existing legislative provisions. The purpose of such amendments is to align the legal framework with the exigencies of technological progress, particularly in the context of facilitating effective crime investigation.

The Criminal Procedure Identification Act 2022 aims to supplant the existing Identification of Prisoners Act of 1920. (The Criminal Procedure Identification Act, 2022) The act delineates the specific categories of data that are permissible for collection, specifies the individuals from whom said data may be collected, and designates the authorized entities responsible for granting permission for the collection of such data. The legislation grants authorization for the acquisition and

subsequent examination of biological specimens, such as blood, semen, hair, swabs, as well as non-biological samples like handwriting and signature, for the purpose of conducting DNA profiling. The specimens may be procured from individuals who have been apprehended or found guilty. Biological specimens may be procured from individuals who are apprehended for perpetrating acts against minors or females, or in cases where the offence carries a minimum sentence of seven years or greater. The authorization to procure samples from individuals is within the purview of a magistrate, particularly in cases where the individual is subjected to preventive detention or is deemed instrumental to an ongoing inquiry. The data has the potential to be retained for a duration of 75 years, or until such time as the individual in question is exonerated in its entirety. (The Criminal Procedure Identification Act, 2022)

7.8. Application of Forensic Evidence and Judicial Pronouncements

In criminal proceedings that rely predominantly on circumstantial evidence, the field of forensic science assumes a paramount significance, as it can aid in the establishment of evidentiary support for the commission of a crime, the identification of the perpetrator, and the determination of the culpability or innocence of the charged individual. One of the primary tasks undertaken by the investigating officer at the location of the crime entails conducting a comprehensive search in order to identify potential evidence that possesses credibility with regards to the crime under investigation.

The officer conducting the investigation should exercise caution to prevent the possible compromise of physical evidence, which tends to proliferate at the crime scene during the processes of gathering, packaging, and transmission. It is imperative to exercise due diligence to safeguard the integrity of evidence and mitigate any potential endeavors to manipulate or compromise the material, thereby preventing any inadvertent pollution or harm.(Publications et al.)

Pritam Singh and Another v. State of Punjab (AIR 1956, SC 415)**:**

An appeal was lodged challenging the verdict of guilt for the crime of murder and the subsequent imposition of the death penalty, as handed down by the trial court and subsequently upheld by the High Court. Footprints were discovered at the location that exhibited a congruence with a set of footwear belonging to the appellant, Pritam Singh Fatehpuri, which were subsequently retrieved from his place of residence. The evidentiary value of the track proof was utilized in relation to the appellant Pritam Singh Lohara, wherein his foot impressions were observed while traversing the sandy path specifically designated for this purpose within the confines of the correctional facility.

It was determined that these prints corresponded with the moulds of the footprints that were contemporaneously prepared at the scene of interest. The court made an observation regarding the rudimentary nature of the science of footprints recognition, suggesting that it cannot be heavily relied upon. However, it acknowledged that track evidence can be considered as circumstantial evidence, in conjunction with other circumstances, to potentially establish the identity of the perpetrator. It is important to note, however, that track evidence alone may not be deemed enough for an indictment.

The court duly noted that the evidentiary value of the track evidence pertaining to the footprints constituted a significant factor that the prosecution could employ against the individuals in question, namely Pritam Singh Fatehpuri and Fateh Singh Lohara.

Santosh Kumar Singh v. State through CB1 (2010 (9), SCC 747)

In this case the appellant, was subjected to a legal process resulting in a verdict of guilt for the offences of rape and murder. The trial court turned down the verdict of acquittal, thereby dismissing the DNA report and other evidentiary materials. The High Court, on appeal rendered a verdict that overturned the ruling of the lower court, specifically with regards to the admissibility and weight assigned to DNA evidence. Consequently, the accused individual was subsequently sentenced to the

ultimate penalty of death. The indictment was upheld by the Supreme Court; however, the death penalty was reduced to life incarceration.

The court observed that a judge is not authorized to supplant their own subjective viewpoint with that of an expert, especially in domains such as DNA profiling. The genetic material extracted from the seminal fluid stains present on the undergarments of the deceased individual, as well as from the swabs and slides collected, has been determined to originate from the accused under examination. The verdict rendered by the trial court lacks justification as no adverse findings could be attributed to the experts responsible for the submission of the reports. The acceptance of the DNA reports as scientifically correct was granted by the Supreme Court.

Murari Lal v. State of Madhya Pradesh (1980 1 SCC 704)

The present case pertains to a homicide wherein a handwritten document was discovered in the quarter of the deceased, disclosing that the perpetration of the crime was executed by individuals possessing a higher education degree but currently lacking gainful employment. According to the expert analysis, it has been posited that the handwritten note and the sample writing of the appellant exhibit a notable degree of similarity. The court, in the process of delivering its verdict, made certain noteworthy observations pertaining to the expert evidence presented. The assertion posits that an expert should not be regarded as an accomplice.

It further highlights the peril associated with placing excessive reliance on the expert's viewpoint, as human discernment is inherently susceptible to fallibility. Consequently, an expert may inadvertently proffer an erroneous opinion due to inherent limitations in their powers of observation or potential errors in their foundational assumptions. It has been noted that the field of handwriting recognition does not possess the same level of precision as that of fingerprint analysis. In each case, it is imperative to duly examine the perspective of a handwriting expert, in conjunction with the presence of substantial corroboration.

To facilitate an impartial assessment by the judge, it is imperative for each specialist to furnish the essential scientific parameters that are requisite for evaluating the veracity of an inference. In the present instance, the court duly affirmed the appellant's conviction predicated upon the concurrence of handwriting samples, which exhibited some correspondence with the written note discovered upon the table of the deceased.

In the case of *Krishan v. State of Haryana* ((2014) 13 SCC 574), the Trial Court, after careful examination of all of the details surrounding the case, placed significant reliance on the report provided by the Forensic Science Laboratory (FSL) to render a conviction against the appellant under section 376 for rape and section 506 for criminal intimidation of the Indian Penal Code 1860.

In a recent judicial decision (Gujarat v. Mohan Hamir Gohil and others R/Cr. A/224/2012), the Division Bench of the Gujarat Court, having duly considered a multitude of authoritative sources on the subject of DNA technology, diverse testing methodologies employed, and the notable scientific progress achieved globally, astutely observed that over the course of time, both domestic and international courts, including those within the jurisdiction of India, have increasingly accorded significant weight to the evidentiary value of DNA outcomes. The observation highlights the significant advancements and increased complexity that the field of DNA testing has undergone over time. These advancements have resulted in consequences that possess the potential to either implicate or exonerate the accused individual.

In the context of the *Nitish Katara murder case* (Vishal Yadav v. State of Uttar Pradesh 2014 SCC online Del. 1373), it is worth noting that the identification of the deceased individual was a challenging task primarily attributed to the limited presence of a fragmentary segment of a singular palm, which had not undergone combustion. In this instance, the utilization of a DNA profile proved instrumental in the identification of the bodily remains. This was achieved through a meticulous

comparison of the DNA profile with that of the deceased's parents. Consequently, this crucial alignment enabled the High Court of Delhi to validate and maintain the conviction of the accused party.

In the case of *Sushil Mandal v. The State* (2014 SCC Mad. 7362), as represented by the Central Bureau of Investigation (CBI), the petitioner, who happens to be the father of the deceased male child, has raised objections regarding the conclusions derived from the process of DNA profiling. The deceased male in the transitional phase of adolescence, experienced a mutual attraction towards a female student. The educational institution, recognizing the situation, advised the respective parents of both parties to exercise vigilance in monitoring their interactions. Subsequently, it was discovered that the young male had been reported as absent, and following a span of seven days, an extensively decayed undetected cadaver was retrieved from a body of water.

The petitioner made a statement asserting his inability to positively ascertain the identity of the deceased individual's remains and attire, which are believed to belong to his son who has been reported missing. The parents in question exhibited a preference for filing a habeas corpus petition in the esteemed high court, wherein they accused the father of the young lady and beseeched the court to issue a directive for the Central Bureau of Investigation (CBI) to conduct a probe. The genetic profiles of the parents (the petitioner and his wife) of the deceased have been found to exhibit a congruent alignment with the DNA test results obtained from the bodily remains.

The test of skull superimposition has additionally served to establish a correlation between the deceased and the subsequently retrieved corpus. However, the petitioner exhibited a persistent reluctance to acknowledge the veracity unveiled by the scientific examinations, employing various pretexts to justify their refusal. This behavior persisted even in the face of the petitioner being afforded the opportunity for reassurance through the repetition of the DNA test. The highest judicial body,

i.e., the apex court, made use of scientific methodologies, such as DNA profiling, in order to establish the verification of the dead body, thus leading to the resolution and subsequent closure of the case.

In the case of *Anmol Singh Swarn Singh Jabbal v. The State of Maharastra* (2014 SCC Bom. 397), the Bombay High Court rendered a verdict affirming a life sentence. This decision was predicated upon the application of DNA evidence, alongside other corroborating evidentiary materials, to establish the culpability of the accused. The accused was found guilty of the murder of a young female engineer, who happened to be a coworker of his, in a tragic incident stemming from unrequited affection.

In another instance, the Delhi police investigated a distressing incident involving the heinous crimes of rape and unnatural sexual acts committed against a four-year-old girl residing in an impoverished urban settlement. Notably, DNA profiling techniques were employed to establish a conclusive connection between the offender and the abhorrent act of sexual assault. Upon careful examination of the comprehensive evaluation of the child's testimony and the different techniques employed therein, the court had duly sanctioned the investigation findings, which were substantiated by DNA reports and other pieces of evidence.

Consequently, the court ruled the accused as guilty and had overturned the exoneration order previously issued by the trial court. (State of NCT Delhi v. Sujeet Kumar, 2014 SCC Del. 1952) The application of DNA technology facilitated the legal proceedings resulting in the conviction and subsequent capital punishment of the perpetrator. The individual in question was found guilty of the heinous crimes of abduction, sexual assault, and homicide committed against a 10-year-old female student. The offender, an auto rickshaw driver, callously disposed of the victim's remains in a flowing canal. (State by the Inspector of Police v. Manoharan, 2015 Cri. L J 1215)

8. Opinions of Scientists and the Courts of Justice

The preceding discourse has predominantly revolved around jurisdictions that adhere to the common law tradition, wherein an adversarial judicial system is employed. These jurisdictions encompass the United Kingdom, Ireland, United States, Canada, Australia, and New Zealand. In this context, it is noteworthy that the police inquiry plays a pivotal role in informing the prosecution's case, as it serves as a foundation upon which the legal contentions are constructed. Conversely, the defense team undertakes the task of diligently constructing evidence in a discrete manner, with the aim of substantiating their claims and effectively countering the prosecution's case.(Alldridge, 1999)

The arguments are subsequently submitted to the court for deliberation, wherein both parties are afforded the opportunity to present their respective positions and engage in the examination of witnesses, including those with specialized knowledge, who have been summoned by the opposing party. The allocation of fact-finding responsibilities in criminal cases is contingent upon the nature of the accusation. Specifically, the task of ascertaining the facts is entrusted to either a magistrate or judge, or in the case of more severe offences, a jury composed of individuals lacking professional legal training, under the guidance and oversight of a judge.(Alldridge, 1999)

In the context of jurisdictions adhering to civil law, predominantly observed in Europe, the legal system operates on an inquisitorial framework, or more accurately, a hybrid model. This entails the involvement of an examining magistrate, who assumes the role of directing the investigative phase, eventually culminating in the presentation of the comprehensive case before a trial process. In this context, it is worth noting that while both perspectives are duly acknowledged, there exists a prevailing consensus regarding the veracity and validity of the evidence, which has been established prior to the commencement of the trial. The prosecution and defense attorneys endeavor to convince the expert witness to adopt their respective viewpoints when assessing the evidence. The adjudication process at the court varies subject to the jurisdiction. In some cases, an expert judge presides

over the proceedings either individually or, more commonly, in conjunction with lay assessors or a jury.(Alldridge, 1999)

In the Scottish jurisdiction, it is pertinent to note that the prevailing legal framework operates under a hybrid system. This system, characterized by its unique amalgamation of distinct elements, entails that the Procurator Fiscal assumes a pivotal role in directing the investigative phase for a majority of grave offences. Subsequently, this investigative stage culminates in an adversarial trial, wherein the parties involved engage in a confrontational legal proceeding.

9. System of Inquisitorial and Scientific Evidence

The distinction between the function of scientific evidence and that of the scientist as an expert witness manifests itself in these two distinct contexts. During the preliminary phase of the inquisitorial legal system, an evaluating magistrate assumes the responsibility of gathering all pertinent evidence. In cases necessitating forensic investigation, the magistrate is tasked with engaging the expertise of scientists to conduct the necessary evaluations and subsequently provide their respective reports. Forensic experts are granted the autonomy to conduct their work with accuracy and fairness, as long as they adhere to the boundaries of their assigned responsibilities.(Alldridge, 1999) Any inquiries, appeals, or objections pertaining to the forensic evidence must be channeled through the magistrate, who possesses complete authority over the scope of examination and the relevance of the results in relation to the construction of the case. When deliberating upon the determination of whether to initiate legal proceedings, and subsequently, the selection of admissible evidence to be offered before the court, the examining judge possesses the autonomy to exercise their own discernment, drawing upon their expertise and, in some cases, even relying on instinct. The absence of established protocols pertaining to the admissibility of evidence, as well as the examination and evaluations of both scientific and non-scientific evidence, is evident.(Forensic

1998.) However, it is imperative that all decisions made by the magistrate are accompanied by a well-founded rationale.

The objective is that, upon the completion of the report by the examining magistrate, all parties involved should have reached a consensus regarding the factual information, which encompasses the findings derived from the analysis of the forensic evidence. In the event that the aforementioned scenario does not transpire, it is worth noting that potential issues from the defense may still arise subsequent to the suspect's formal charging. However, it is crucial that these objections be addressed and settled prior to the submission of legal documents to the court. In this manner, the comprehensive resolution of any concerns pertaining to expert evidence, encompassing its meticulous assessment, interpretation, and, ideally, its evaluation, ought to be concluded prior to the commencement of the trial.(Forensic 1998.)

10. Comparing Inquisitorial and Adversarial System

In the context of the inquisitorial system, it is pertinent to note that the courtroom no longer serves as a platform for the exchange of scientific perspectives or the rigorous questioning of expert witnesses. It could be contended that the exclusion of scientists' capacity to sway the court through their authoritative status as experts, or to express the intensity of their opinions through theatrical exhibition, serves to mitigate any potential diversion from the objective facts and their subsequent analysis, thereby fostering an environment conducive to the administration of more equitable justice.

Conversely, legal practitioners, through their omission to actively participate in the intricacies of scientific discourse, may possess a diminished comprehension of the extent and constraints of scientific knowledge. Consequently, they may inadvertently permit the unopposed acceptance of both the calibre of scientific inquiry and the corresponding expert opinions. In contemporary times, it is

noteworthy to observe that a significant proportion of scientific evidence is predominantly disseminated in the form of written reports.

Nevertheless, it is worth noting that in the event that judges are provided with comprehensive evidence prior to the commencement of a trial, they may acquire a more extensive understanding and receive thorough instructions regarding the scientific matters at hand, surpassing what would typically be attainable within the confines of an adversarial system. However, one could posit that the inquisitorial system fosters a milieu wherein scientific viewpoints are perceived as flawless, notwithstanding the possibility of being contested by the magistrate. Consequently, in the dearth of any deliberation, particularly regarding the elucidation and assessment of evidence, the administration of justice is compromised to a greater extent.(J. Fraser & Williams, 2013)

One of the ramifications stemming from the absence of admissibility thresholds within the inquisitorial system is the inclination to address uncertainties pertaining to the credibility of scientific evidence by means of the probative value ascribed to said evidence. By engaging in such an approach, the discernible matters pertaining to the dependability of scientific findings, on one hand, and the process of assessment, on the other, may become entangled, albeit to a certain extent, which may also occasionally transpire within the adversarial system, albeit not as a customary occurrence.

The allocation of duty for upholding the dependability of scientific evidence within an inquisitorial jurisdiction is frequently ambiguous and lacks clarity for the parties concerned.(J. Fraser & Williams, 2013) However, in the event that the interactions among the scientist, the defense, and the examining magistrate are conducted with efficacy during the preliminary inquiry, the principle of "equality of arms" is upheld, as both parties are granted comparable opportunities to obtain and scrutinize the forensic evidence, as well as its subsequent evaluation and comprehension. Despite the comparatively restricted availability of forensic

scientists within the field, wherein a smaller number of individuals are involved in each case as compared to the adversarial system, the implementation of accreditation or approved lists of experts serves to uphold the calibre of individual scientists.

However, it is important to note that the complete elimination of incapable practitioners is not guaranteed. In conjunction with the impartiality exhibited by the examining magistrate, these aforementioned factors are designed to mitigate the presence of prejudiced expert testimonies.(Forensic 1998.)

The efficacy of expert scientific testimony within the inquisitorial judicial process is contingent upon the optimal operation of all aforementioned factors. In contrast to the adversarial system, the absence of a conclusive debate on the evidence via cross-examination in the presence of the fact-finders precludes the opportunity to detect inaccuracies, misunderstandings, and exaggerated opinions. However, it is worth noting that certain individuals may argue that this forum is not the most suitable platform for discussing and resolving frequently intricate matters. In essence, it can be concluded that both systems fail to provide an optimal resolution to the intricate task of managing scientific evidence within the judicial framework. This deficiency primarily pertains to the domains of admissibility, reliability, as well as the interpretation and assessment of evidence. These facets, in turn, constitute the fundamental pillars of expert testimony within the courtroom.(Forensic 1998.)

11. Role of Scientific Expert in the Court

The professional obligations associated with the role of a forensic expert, in their capacity as a scientist, exhibit a significant degree of congruence with the responsibilities undertaken by scientists operating within diverse domains. In the realm of criminal justice and within the confines of a court of law, it is imperative that the scientific expert fulfils a higher set of expectations. A notable disparity exists between the objective assertions derived from scientific research and the

legal discourse surrounding the particular case to which the forensic evidence pertains.

The court exhibits a keen desire to comprehend the ramifications of the scientific discoveries. Specifically, both the prosecution and defense factions express a shared interest in assessing its relevance to the respective arguments presented by each party. The presiding judge must ensure that the court, as an entirety, is diligently ascribing appropriate significance to the forensic testimony and conscientiously evaluating it within the framework of the case. In numerous judicial settings, the non-expert jury members, commonly referred to as lay jurors, are tasked with the responsibility of assessing the relative weight of forensic evidence presented by both the prosecution and defense. This task is particularly challenging for lay jurors due to their limited knowledge and experience in both legal and scientific domains.(C. Adam, 2016)

Within the broader framework of this context, it is imperative to consider the ways in which the scientific expert witness can provide valuable assistance to the court. Furthermore, it is essential to deliberate upon the most appropriate manner in which the testimony should be offered. Lastly, it is of utmost importance to carefully contemplate the process by which an opinion should be constructed and effectively communicated to the court. The issues have engendered extensive deliberation and apprehension, especially over the last three decades, propelled by the occurrence of overruled verdicts subsequent to appeals.(J. Fraser & Williams, 2013)

The primary objective of contemporary forensic scientists should be to offer an equitable and well-pondered viewpoint regarding the evidence, thereby aiding the judicial system in arriving at a sound and enduring verdict. This statement delves into the crux of the matter, namely the essence of the expert opinion pertaining to the evidence proffered by the scientist, and the process by which said opinion is incorporated into the judicial proceedings. The proficient individual is obligated to impart knowledge to the individuals responsible for gathering information, in order

to enable them to comprehend and scrutinize the expert evidence. This scrutiny aims not only to assess its precision and consequently its dependability, but also to form their own perspective regarding its interpretation and importance, regardless of the expert witness's offered opinion. The absence of any inclination on the part of the jury to unconditionally yield to expert authority is evident.(Forensic 1998.)

The task at hand necessitates the expert to articulate the testimony in a manner that is comprehensible not solely to the legal practitioners, but also to the non-specialist individuals comprising the jury. The task at hand presents itself as a substantial and noteworthy endeavor. The initial challenge pertains to the technical aspects that form the foundation of the evidence evaluation. The second aspect pertains to the formulation and articulation of the ultimate opinion. The fact-finders anticipate the expert to provide an assessment regarding the importance of the evidence.

12. Expert Witness Obligations and Liabilities(Alldridge, 1999)

1. It is imperative that the perspective of the specialist remains objective, impartial, and confined to their respective domain of expertise. The primary duty of the expert lies with the court, prioritizing its interests over those of the instructing party.
2. It is imperative to establish credible substantiation of the expert's qualifications.
3. Experts must adhere to the confines of their respective domains of expertise, and any deviation from this should be explicitly disclosed to the court.
4. The expert is obligated to furnish the court with a comprehensive factual foundation that underpins their standpoint, refraining from omitting any information that may undermine said opinion.
5. In the event that the expert possesses expertise of alternate methodologies for evaluation, divergent perspectives on the scientific underpinnings of the work, or different justifications that could account for the evidence, it is incumbent upon them to elucidate these to the court.

The significance of adhering to these guidelines becomes particularly pronounced in instances where the scientist is not summoned to provide verbal testimonies. In the event that there are divergent expert witness assertions to be laid out, it is customary to arrange for a preliminary discourse prior to the hearing. The purpose of this discussion is to ascertain the areas of concurrence among the experts as well as those that are subject to disagreement. The expert's commitment to upholding legitimate standards and principles has become increasingly emphasized in the realm of academia. This includes the imperative to offer observations and opinions with utmost honesty and sincerity, devoid of any personal biases or hidden agendas. Additionally, the expert is expected to navigate potential disagreements of interest with utmost transparency and integrity. Furthermore, the preservation of confidentiality has emerged as a crucial aspect of ethical conduct within the courts.(Alldridge, 1999)

13. The Assessment and Regulation of Evaluation and Opinion.

The proficiency of the specialist and the caliber of both the technique and the laboratory are pivotal elements that can potentially impact the dependability of the specialist's testimony and, in certain instances, may directly result in inaccuracies, or in the most severe scenarios, miscarriages of justice, within the judicial system. Considering this, it is noteworthy that entities entrusted with the duty of overseeing the quality of forensic facilities have formulated accreditation guidelines and descriptions of practice. These measures serve as mechanisms to guarantee the dependability and soundness of forensic tests and measurements, which are subsequently presented as evidence in legal proceedings.(Houck, 2015)

The ISO, also known as the International Standards Organization, is responsible for the publication of the ISO 17025 standard. This standard outlines the broad criteria that testing, and verification laboratories must meet to demonstrate their proficiency. Accreditation is granted to laboratories that successfully adhere to the ISO 17025 standard and are involved in the evaluation and validation of materials.

The statement delineates the fundamental international criterion governing the laboratory examination of forensic substances. Nevertheless, it is imperative to acknowledge that the guarantee of quality in the comprehensive forensic procedure extends beyond the considerations. It is worth noting that the standards pertaining to various other facets of this technique are currently not as extensively established.

14. Standards of Behavior and Procedure

The obligations expected from the scientist, with regards to their professional and technical proficiency and application, collectively constitute a set of ethical principles. These supplementary responsibilities can be succinctly summarized as:(Champod & Vuille, 2011)

1. It is imperative for the scientist to uphold and augment professional expertise by means of diligent analysis and conscientiousness towards research and other advancements within the respective domain.
2. The preservation of evidentiary consistency holds paramount significance in the context of forensic investigation and evaluation, necessitating the shared accountability of all individuals involved in the handling of specimens.
3. The scientist ought to exhibit diligence in acquiring pertinent details regarding the facts surrounding the case, as this data may significantly provide the accurate understanding and comprehensive assessment of the experimental outcomes.
4. It is crucial to exclusively employ verified and endorsed experimental and interpretational methodologies in the context of casework.
5. The scientist ought to thoroughly examine all discoveries and their explication in consideration of any novel data or advancements in the matter.

6. The scientific practitioner must consistently maintain a state of readiness to respond in any circumstance that is perceived to have the potential to result in an erroneous administration of justice.

The standards of practice are applicable throughout the entirety of the forensic cycle, encompassing all stages from the initial crime scene investigation to the ultimate presentation of expert assessment within the court of law. It is expedient to categorize these elements into two distinct groups: those pertaining to the administration and supervision of the laboratory, encompassing the control of exhibits, and those that pertain to the procedural aspects of analyzing and interpreting the obtained findings. The laboratory bears the obligation of overseeing the administration of training programs for its entire staff, with a particular emphasis on conducting periodic evaluations to gauge their level of technical proficiency.(Champod & Vuille, 2011)

The application of accreditation standards pertains to the meticulous determination and approval of suitable test techniques, encompassing the methodologies employed for data evaluation and interpretation. It is imperative that all analytical strategies possess an approval report that exhibits the capacity for external verification. It is essential to ensure comprehensive documentation of databases and reference collections within the laboratory, in order to facilitate users in making informed assessments regarding the suitability and relevance of these materials.

Furthermore, it is imperative to employ inter-laboratory comparisons and assessments of competence as a means of validating testing processes in comparison to those utilized by other institutions. In conclusion, it is vital to present the findings in a suitable manner that caters to the user's needs. Moreover, it is crucial to ascertain the existence of pertinent published material that forms the foundation of the research. Additionally, it is essential to furnish proof supporting the soundness of the technique employed and evaluate any ambiguities, be they

experimental or otherwise, that may influence the inferences drawn from the examination.(J. Fraser & Williams, 2013)

15. Expert's Verified Credentials

The absence of objective limit standards for the identification and validation of a person as an expert, thereby establishing their complete eligibility to provide scientific opinions within a court setting, is evident. In the context of the inquisitorial system, it is pertinent to note that the court exercises a considerable degree of discretion in rendering its decisions, primarily relying on a case-by-case approach. However, it is worth mentioning that the examining magistrate, operating within the framework of this system, may consult pre-approved rosters of experts to aid in the judicial process. For individuals employed within substantial laboratory settings, functioning under the auspices of an institutional accreditation, the mere fact of such affiliation inherently serves as a testament to their specialized knowledge and esteemed standing. This option is not accessible to individuals assuming the role of independent consultants.(Forensic 1998.)

In recent years, notable advancements have been made in the pursuit of enhanced uniformity and comprehension pertaining to the responsibilities of expert witnesses. These advancements aim to establish a framework through which expert witnesses can effectively contribute to the admissibility and reliability of scientific opinions within the judicial system, irrespective of the jurisdiction in which they are engaged. Notwithstanding the existence of comprehensive excellence standards, the task of formulating opinions, both in a general sense and within specific subdisciplines, poses an even more formidable difficulties for the scientific community.(Forensic 1998.)

16. Concluding Remarks

It is of utmost utility to succinctly encapsulate the myriad of concerns pertaining to admissibility that have emerged throughout the entirety of these cases, as well as

others, and to discern their implications on the fundamental criteria of relevance and reliability. The establishment of evidentiary validity beyond the realm of general court understanding, coupled with the acknowledgment of the witness's expertise, are standards that have been widely accepted and integrated into the legal systems of various countries for a considerable duration. Nevertheless, instances might occur in which the presiding adjudicator perceives the opinion, whether in its entirety or partially, as a matter that the jury is fully capable of assessing without the need for expert guidance. An additional matter of significance pertains to the determination of the extent to which the court must engage in assessing the appropriateness and adequacy of the expertise being offered, in order to establish its reliability and accuracy within the unique circumstances of each individual case.(Page et al., 2011)

The Daubert criteria, as applied within the United States, comprehensively address the matters in a methodical manner, albeit with a level of linguistic precision and elaboration surpassing that found within the present abridged exposition. Similar domains of discourse have arisen in Canada, albeit not as overtly as in the Daubert framework. These topics are, to some degree, intertwined with considerations of relevance and expertise. In stark contrast, it is noteworthy that both Australia and England have approached these requirements in a manner that exhibits a higher degree of adaptability.

This is achieved through the careful calibration of reservations regarding admissibility, particularly in cases where concerns arise pertaining to the reliability of evidence. Such reservations are juxtaposed against the overall significance attributed to the opinion by the jury. Conversely, the judicial bodies in these respective jurisdictions have exhibited a more prudent approach by emphasizing the utmost significance of ensuring that the jury is adequately apprised of the logical progression that guided the expert witness from the factual underpinnings to the formation of their professional viewpoint.(Page et al., 2011)

A prevalent characteristic observed in the evaluation of admissibility pertains to the potential utilization of a distinct hearing or *voir dire* procedure, such as the Daubert hearing in the United States. This procedure allows for the determination of admissibility to be made independently of the jury's participation and prior to the commencement of the trial, commonly referred to as *in limine.* Despite the courts' cognizance of the importance of reliability and the endeavors, such as the Daubert standard, to establish the evaluation of reliability as a pivotal factor in determining admissibility, there exists substantiated evidence suggesting a lack of consistent adherence to this principle within the judicial practices observed across various jurisdictions.(Page et al., 2011)

The paramount concern that has arisen from this discourse pertains to the methodology employed by the jury in determining the probative value of evidence, and its correlation with the substance of any assessment proffered by expert testimony. The primary objective of the Daubert approach was to establish a mechanism that would guarantee the admission of scientifically sound and credible evidence in court proceedings, thereby assuming the role of a gatekeeper. Its purpose was to make certain that only those outcomes derived from scientific endeavors that had undergone rigorous quality assurance measures, ensuring their reliability and validity, could be presented to the jury.

The matter pertaining to assessments was not explicitly elucidated within the confines of these regulations, as their primary objective was to tackle matters of admissibility. Ideally, the admissibility of expert evidence hinged upon its conformity to established criteria, and subsequent to such scrutiny, the jury exercised its discretion in evaluating the probative value of the evidence, cognizant of the scientific validity and substantiation thereof. Alternatively, in instances where the expert opinion failed to meet the requisite standards, it was deemed inadmissible and consequently eliminated from consideration. Nevertheless, certain courts in England and Australia have indeed expressed a favorable

disposition towards the admission of evidence that possesses unproven reliability, wherein the jury subsequently undertakes an evaluation of its significance.

In the preceding decade, the discourse surrounding the admissibility of evidence has emerged as a pivotal factor, prompting comprehensive evaluations of legal statutes and standards pertaining to expert testimony. This development has been propelled by the growing recognition of the imperative to ascertain the dependability of evidence and the methods by which such reliability can be effectively established. The prominence of forensic science has been more pronounced in the United States, whereas in England, the primary concern has revolved around the courts' incongruous procedures to assessing reliability.

In the context of the Indian Evidence Act, 1872 (now the Bharatiya Sakshya Adhiniyan 2023) scenario, there has been a notable surge in the prioritization of employing forensic innovations within the realm of criminal investigation and legal proceedings. The Commissions tasked with the examination of criminal justice reforms have consistently emphasized the potential benefits of integrating technology into the realm of crime identification, asserting that such integration has the capacity to enhance the overall efficiency of the legal system.

Over the course of time, the pertinent legislations have undergone modifications in order to accommodate the incorporation of forensic techniques within the realms of criminal inquiry and judicial proceedings. However, it can be argued that there are inherent deficiencies within the legal framework that necessitate attention and rectification. The courts exhibit a certain degree of hesitancy in placing reliance on scientific evidence, primarily attributable to their cautious and restrictive approach. Additionally, the courts are deterred from wholeheartedly embracing scientific evidence because of expected inherent shortcomings that are often observed in the presentation and production of such evidence within the judicial setting. The primary objective of the criminal justice system revolves around the provision of equitable dispensation of justice. Without a doubt, it can be asserted that forensic

evidence possesses a higher degree of authenticity when compared to ocular evidence. The inclusion of forensic science as a form of scientific evidence within the criminal justice system is undeniably advantageous. To make progress, it is imperative that we surmount the prevailing deficiencies.

CHAPTER VI

PROSPECTS AND CHALLENGES CONCERNING THE RELEVANCE AND APPLICABILITY OF FORENSIC SCIENCE

1. Introduction

The correct analysis and interpretation of evidence in the realm of criminal justice holds paramount importance in ensuring the efficient operation and authority of justice systems in democratic nations. Consequently, a perpetual imperative exists to continually enhance the precision and dependability of forensic analytic methodologies, commonly referred to as forensic science. The optimal approach for addressing this requirement entails harnessing the comprehensive potential of scientific inquiry to address inquiries and methodologies within the realm of forensic science.

In the context of governmental operations, it is observed that numerous organizations are engaged in the pursuit of research endeavors pertaining to forensic science, either by means of direct involvement or by providing auxiliary assistance. However, a notable dearth of strategic cooperation and leadership is evident within this domain. The ramifications encompass unfulfilled necessities, despite occasional superfluous duplications, and overlooked prospects.(N. A. of Sciences, 2015)

The presence of dependable and accurate forensic science analytical methodologies holds utmost significance in establishing a reputable, equitable, and empirically grounded criminal justice framework

There exists a consensus among scholars that the scientific underpinnings of certain forensic science methodologies presently in use necessitate fortification, while the development of supplementary, more efficacious approaches is of utmost importance and immediacy. The fulfilment of these demands can solely be achieved through the implementation of continuous research initiatives that are explicitly formulated to guarantee and enhance the dependability and accuracy of existing methodologies, while simultaneously promoting the advancement and use of novel and superior processes.

The present undertaking presents a formidable challenge, owing to the expansive scope inherent within the domain under consideration. The realm of forensic science encompasses a broad spectrum of concerns, spanning from the meticulous examination of crime scenes to the comprehensive analysis of diverse forms of evidentiary material.(N. A. of Sciences, 2015)

Furthermore, the practice of forensic science is enriched by a multitude of diverse fields of study, encompassing but not limited to biology, chemistry, statistics, and various additional areas of study. In light of the various obstacles encountered by forensic science laboratories, including limited resources, overwhelming caseloads, and discrepancies in operational structures across state and local jurisdictions, it is imperative that national leadership takes immediate action to establish and maintain a comprehensive initiative of exceptional calibre.

This initiative should be centred around conducting targeted research in the field of forensic science, with the ultimate objective of enhancing and improving the criminal justice system.(N. A. of Sciences, 2015) The progression of societal dynamics, coupled with the proliferation of technological advancements and the cultivation of innovative practices, has engendered the emergence of increasingly intricate manifestations of criminal behavior, as well as novel modalities of perpetration. To maintain a continuous connection with the ever-changing landscape of advancements, the criminal justice administration system has

consistently undergone transformative developments, utilizing a diverse array of investigative methodologies and judicial procedures to consistently remain one stride ahead. The utilization of innovations in technology and scientific advancements has indeed facilitated the endeavors of malefactors. However, it is imperative to acknowledge that the progression of scientific methodologies pertaining to the acquisition of evidence and the conduct of investigations has unquestionably bolstered the capabilities of law enforcement departments and judicial entities in safeguarding the well-being of the populace.

Scientific methodologies, such as Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS),(Dodds et al., 2010) High-Speed Ballistics Photography, 3D Forensic Facial Reconstruction, Magnetic Fingerprinting, and Automated Fingerprint Identification (AFIS), have revolutionized the field of forensic investigation by offering advanced techniques for proof gathering and evaluation. These cutting-edge innovations have ushered in a paradigm shift, resembling a futuristic strategy, in the domain of forensic Science.

2. Polygraph and Narcoanalysis Tests in India

In numerous instances involving criminal proceedings, pertinent data is obtained through the process of questioning from the individuals who stand accused. The process of interrogating the accused holds significant importance in the acquisition of evidentiary material pertaining to a specific criminal incident. During the process of interrogation, it has been noted that the accused party consistently maintains a state of silence and exhibits a tendency to evade the act of responding to the inquiries posed by the investigating authorities.(Laxmi & Buchiya, 2019) In such circumstances, the investigating agencies find themselves bereft of alternative courses of action, compelling them to resort to the implementation of a third-degree methodology to extract pertinent information.(Laxmi & Buchiya, 2019)

In the third-degree method, it is customary to employ coercive or forceful tactics to elicit information that is believed to be within the knowledge of the suspect. In the

contemporary epoch characterized by the prominence of human rights, the utilization of coercive methodologies by investigative entities for the purpose of extracting data is deemed to be utterly impermissible. Advocates of the employment of scientific methodologies such as Polygraph and Narcoanalysis contend that their utilization is imperative in the current era characterized by a burgeoning crime rate.

Conversely, detractors of these tests raise objections based on the infringement of constitutional guarantees and an abuse of the human rights of the accused. The utilization of the "lie detector test" holds a distinctive position within the annals of human history, as references to "lie detecting devices" can be traced back to the Mediaeval era. During this epoch, rudimentary mechanisms and doctrines were employed to discern the veracity of individuals, distinguishing between those who were truthful and those who were not.(Grubin & Madsen, 2005)

2.1. Delineating Polygraph Test

Many instances go unprosecuted due to the absence of definitive proof. These scenarios were ideal for the polygraph exam. Polygraph tests detect pulse, blood pressure, sweat, and more by attaching equipment to the body. The test assumes one's incorrect assertions would cause variables to deviate from their norms.(Agarwal et al.) A test subject's assertion is judged by the distinction between variables when deceitful and when normal.

The historical trajectory of studying physiological and psychological reactions as a means of identifying individuals involved in criminal activities spans a considerable duration. One of the earliest documented occurrences of such phenomena can be traced back to the year 600 BC, as evidenced by the textual records found in the Sushrutha Samhitha and Charaka Samitha. These texts hold significant importance as they are regarded as the fundamental sources of knowledge in the field of Ayurveda. It discusses the techniques employed in the identification of an individual engaged in the act of poisoning through the

meticulous observation and analysis of alterations in their physiological and psychological demeanor.

The extant literature from the early Western civilization also alludes to the application of an individual's pulse and blood pressure as a means to discern falsehood, as evidenced by the inclusion of such a practice in the *Gesta Romanorum*, a compendium originating from the 13th century.(Gesta Romanorum: Or, Entertaining Stories Invented by the Monks as a Fire) Throughout history, various rudimentary techniques, including those rooted in superstition such as ordeal and brutality, have been employed.(Larson, 1932) However, it was not until 1921 that a significant advancement in the realm of lies detection occurred with the advent of the Polygraph. This groundbreaking invention can be attributed to the pioneering work of physiologist John A. Larson. Larson ingeniously developed a device capable of concurrently monitoring and quantifying fluctuations in blood pressure, heart pace, and breathing speed.

The primary objective of this innovative contraption was to facilitate the identification of deceptive behavior.(Synnott et al., 2015) The inaugural intersection between the Polygraph test and the legal system occurred in the year 1923, within the seminal American legal case of Frye v. US. (Frye v. US, 293 F. 1013 (D.C. Cir. 1923) Subsequent to its inception, the Polygraph tests have undergone a series of advancements and witnessed the incorporation of novel methodologies, all in a concerted endeavor to enhance its efficacy and render it impervious to deception.

The sector of Polygraph tests in the United States is valued at $2 Billion, indicating its significant economic impact. Over time, advancements in this field have emerged, including Eye-Scanning, Brain Mapping, and the prospective integration of Artificial Intelligence technologies. These innovations aim to enhance the reliability and effectiveness of the Polygraph system, striving for a higher degree of accuracy and error reduction.(Harris, 2018) This system for acquiring scientific

evidence has, nonetheless, encountered a complex and dynamic association with legal systems on a global scale. The incorporation of novel developments in technology within legal systems pertaining to criminal justice has been a subject of ongoing deliberation among legal scholars and judges. However, persistent concerns surrounding the dependability of these techniques have consistently emerged as a significant matter of contention.

2.2. The Acceptability of Polygraph Examinations in India

The inaugural reference to Polygraph tests within the judicial framework of India was documented in the seminal case of *Sekharan & Others v. State of Kerala* in the year 1979. (Sekharan & Others v. State of Kerala, 1979 KLT 337) Without delving into an extensive evaluation of the admissibility of evidence obtained through scientific methodologies, it is worth noting that the court did express its reservations regarding the overall lack of credibility associated with Polygraph tests, hypnosis, and Narco-analysis.

The court expounded upon their rationale by positing that although these approaches serve to enhance the veracity of information, it is the pursuit of justice that the court must endeavor to attain. (Sekharan & Others v. State of Kerala, 1979 KLT 337) The admissibility of Polygraph tests was first judicially examined in the year 2004. The present case, Ramchandra Ram Reddy & Others v. The State of Maharashtra, (Ramchandra Ram Reddy & Others v. The State of Maharashtra, Cr. W. P. No. 1924 of 2003) involves an issue raised by the petitioners regarding the legality of Polygraph tests. The petitioners contend that the administration of such tests infringes upon their rights as guaranteed under Article 20(3) of the Constitution of India. The court was confronted with the issue of whether the imposition of a mandatory test on an individual without their consent would constitute a violation of their right against self-incrimination, as protected by Article 20(3). Furthermore, the court had to determine whether the safeguard provided by Article 20(3) is triggered upon the individual being notified of the

requirement to undergo such a test, which they contend infringes upon their rights under Article 20(3). (Ramchandra Ram Reddy & Others v. The State of Maharashtra, Cr. W. P. No. 1924 of 2003)

The court conducted a thorough analysis of the original motive of the drafters and subsequently arrived at the determination that Article 20 of the constitution serves to safeguard people from being coerced into providing self-incriminating testimony, specifically pertaining to the employing of statements given by the accused against their own interests. The court has rendered a declaration asserting that the evidentiary value of information obtained through the use of a Polygraph test does not inherently possess the characteristics of a formal statement.

Furthermore, it is imperative to undertake a critical analysis of the operational methodology employed by the Polygraph test, while simultaneously acknowledging that the outcomes derived from said test merely substantiate the veracity of falsehoods uttered by the individual subjected to the examination. The determination of the falsehood and the nature of the knowledge held by the implicated party regarding the offence remain elusive. (Ramchandra Ram Reddy & Others v. The State of Maharashtra, Cr. W. P. No. 1924 of 2003)

Henceforth, drawing from this logical trajectory, the court arrived at the determination that carrying out of a Polygraph test without the prior approval of an individual does not engender the safeguard provided by Article 20(3). Given the court's focus on the legality of Polygraph tests, it refrained from engaging in an assessment of the tests' credibility. In the year 2008, the Sessions Court of Pune rendered its judgement in the case of State of Maharashtra v. Aditi Baldev Sharma & Anr. (State of Maharashtra v. Sharma, 2008 Cr. C., No. 508/07) Notably, the court placed significant reliance on the use of polygraph tests and a contentious methodology known as Brain Electrical Oscillation Signature (BEOS) to secure the conviction of the defendant, Aditi Sharma.

The present case underscored the necessity for the establishment of a standardized framework for assessing scientific evidence, independent of the expert witness's validity and reliability, despite the existence of considerable circumstantial legal precedents that arrived at the same outcome.(Jurimetrics, 2010.) The Supreme Court's reflection on the constitutionality of scientific approaches, specifically Polygraph tests, in the case of *Selvi and Ors v. State of Karnataka* (Selvi v. State of Karnataka, (2010) 7 SCC 263), marked a significant milestone. This case provided a convincing examination of the constitutional validity of employing such procedures for evidence collection within the court system. The ruling of the court effectively invalidated the position espoused in the *Ramchandra Ram Reddy case*.

The judges of the Bombay High Court had previously rendered a verdict stating that evidence obtained through the application of Polygraph tests did not possess the attributes of a formal statement or testimony, and thus did not infringe upon the rights guaranteed under Article 20(3) of the Constitution. However, in the present case, the Supreme Court ruled that the outcomes constructed from these tests exhibited a distinctive "testimonial" quality. The court provided an elaborate elucidation regarding the extent of rights encompassed within the purview of Article 20(3).

The primary objective of Article 20(3) is to mitigate the occurrence of coercive actions that involve the transmission of personal information that holds pertinence to the matters under consideration. When analyzed in conjunction with Section 161(2) of the Code of Criminal Procedure, (The Code of Criminal Procedure, 1973 s. 161(2) the provision outlined in Article 20(3) serves to safeguard the rights of not only the accused individuals but also the witnesses who undergo examination during the investigative proceedings. The court has reached its verdict that the admission of test findings in a legal proceeding is impermissible if said results have been procured through the exertion of coercion.

The court, in its pursuit of advancing legal principles, determined that it is impermissible to compel any person to submit to such a test, whether it be in the context of criminal investigations or any other circumstances. It has been expounded upon that engaging in such an action would constitute an encroachment upon the inherent freedom of a person. The decision, nevertheless, has allowed for the possibility of administering tests such as the Polygraph test or Narco-analysis on an individual, provided that their consent is obtained.

However, due to the inherent lack of credibility associated with such tests and the absence of conscious control exerted by the test subject over their responses, it has been concluded that the results obtained from these tests alone cannot be deemed admissible as evidentiary material. The admissibility of test results in isolation is limited; however, any details derived from the voluntary administration of such tests may be admissible if it complies with the provisions outlined in *section 27* of the Evidence Act of 1872.

The court underscored the necessity of implementing sufficient measures to ensure the proper administration of said examinations. It is imperative to conform completely to the "Directions for the Administration of Polygraph Test (Lie Detector Test) on an Accused" as released by the esteemed National Human Rights Commission (NHRC) (Guidelines on Administration of Lie Detector Test, 2020) when carrying out any such examination.

The Indian legal framework lacks a definitive rule for assessing the veracity of scientific evidence presented within the judicial system. The incorporation of expert evidence into the Indian legal system is facilitated by section 45 of the Indian Evidence Act, 1872. This provision serves as the technical avenue through which scientific advancements and technological innovations are acknowledged and embraced within the legal framework of India.

In the absence of an established standard, the veracity of scientific evidence is contingent upon the expertise and credibility of the individual presenting it.

Consequently, it becomes incumbent upon the opposing party to challenge and refute the evidence put forth by the expert, employing a case-specific approach. In the matter of the Selvi case, the Supreme Court, drawing upon the prevailing understanding of the inherent limitations and lack of reliability associated with Polygraph tests, rendered a decision whereby the evidentiary value of Polygraph test results was deemed to be inconclusive and thus inadmissible in its raw form.

In lieu of the existing procedure, the test results would gain admission making use of section 27 within the Indian Evidence Act 1872.

This statement suggests that the admissibility of evidence in court is contingent upon the acquisition of additional knowledge derived from the use of the Polygraph test. In the context of a polygraph examination, it is pertinent to note that the individual undergoing the test is indeed required to provide a verbal account, which is further compounded by the potential influence of pharmacological substances.

The cognitive faculties of the individual in question have undergone a process of conditioning, thereby giving rise to the argument that he is subject to external forces that exert a compelling influence upon him. The potential admissibility of a truth serum test is contingent upon its ability to satisfy the criteria outlined in Article 20(3) of the relevant legal framework. Specifically, for such a test to be subject to scrutiny under this provision, it must possess the characteristic of inculpating and incriminating the individual who undergoes the test.(Dalal et al.)

The veracity of the statement can only be determined subsequent to the administration of the test, rather than prior to it. Subsequent assertions of this nature shall be deemed inadmissible as evidentiary material, albeit their potential utility in the context of investigative endeavors. One could posit that the administration of said examination has the potential to induce cognitive impairment and, in extreme cases, may result in a state of unconsciousness or fatality due to excessive dosage. Consequently, this practice contravenes the entitlement safeguarded by *Article 21* of the Constitution.

Henceforth, in accordance with previous assertions, it is imperative that the court bestow authorization for the execution of narcoanalysis solely under extraordinary situations, while ensuring that the examination is carried out under the supervision of proficient professionals. While it is possible that the drafters of the Constitution had the intention of safeguarding individuals accused of crimes from the perils associated with self-incrimination, it is unlikely that they intended to impede the process of conducting thorough and efficient investigations or to hinder the prosecution of criminals. The purpose of protecting an accused person from being compelled to incriminate themselves is equally important as empowering law enforcement agents and the judicial system with the necessary authority to apprehend and bring perpetrators to justice.(Dalal et al.)

Both narco-analysis and polygraph tests have been subject to significant criticism within academic and professional circles. The degree to which it can be employed for the purpose of extracting covert data remains unelucidated. As per the ruling of the Supreme Court, it is imperative to obtain the consent of the subject to proceed with conducting said test. Despite the voluntary agreement of the subject, it is imperative to acknowledge that the outcomes derived from tests conducted cannot be admissible as evidentiary material within the context of legal trials.

However, it should be noted that any data or information that is obtained subsequent to the administration of the test, based on the data extracted, may be admissible as evidentiary support within the legal framework. To enhance the authenticity of narco-analysis and polygraph tests, it is imperative that these methodologies undergo comprehensive and rigorous research. It is necessary to conduct a comprehensive and meticulous investigation to ascertain the sensitivity and specificity of the subject matter at hand(Shelton, 2010).

It is imperative to establish unambiguous standard operating procedures and rules for the execution of these examinations, while duly acknowledging and upholding the fundamental human rights of the individuals involved. The formulation of this

must be undertaken in a manner that is grounded in scientific principles, respects fundamental human rights, and adheres to constitutional frameworks. The attainment of such a possibility can only be realized through the diligent pursuit of rigorous research.

Upon successful completion of these tests, it will be demonstrated that this particular approach is the most effective means of extracting information, surpassing the archaic practice of employing third-degree torture. The utilization of this technology has the potential to serve as a formidable instrument within the realm of forensic science, wielded by investigative entities in their pursuit of identifying, charging, and subsequently bringing to justice individuals who have committed unlawful acts. In doing so, it serves to safeguard the innocent from the grasp of legal entanglements.(Shelton, 2010)

3. DNA Profiling

The integration of scientific genetic-based evidence, specifically DNA profiling, within the context of legal case examination procedures necessitates a harmonious convergence between the domains of science and law, each of which possesses distinct organizational requirements, benchmarks, and obligations. The amalgamation of these two fields of study is primarily oriented towards the objective of upholding justice in diverse scenarios, while simultaneously upholding their respective independence without compromising it.(S. J.-J. of Law et al.)

The utilization of DNA technology in contemporary scientific breakthroughs has emerged as a pivotal factor in the facilitation of legal safeguards and the maintenance of societal order.(L. H.-D. LJ & 2004, 2004) The pervasive utilization of DNA data for the purpose of identifying perpetrators and safeguarding the rights of the innocent, namely by exculpating those who have been wrongly indicted, stands as a highly noteworthy illustration of the profound developments and transformative influence of DNA technology. This technological innovation serves to enhance the efficacy and precision of the system of justice.(L. H.-D. LJ, 2004)

The primary objectives in the pursuit of justice incorporate the detection of perpetrators and the safeguarding of individuals who may be wrongly accused.(Clarke, 2007) DNA specimens and profiles play a pivotal role in the realm of identification, serving as invaluable tools in various contexts. One such use is the recognition of individuals affected by catastrophic events, wherein DNA analysis aids in establishing the identities of victims. Furthermore, these samples and profiles prove instrumental in the detection of potential perpetrators, covering individuals implicated in heinous acts such as sexual assault and homicide. Furthermore, this technology proves to be highly advantageous in the realm of parentage testing and the resolution of immigration cases, particularly when there is uncertainty surrounding familial ties or identity.(K. P.-U. S. L. Rev. 2013.)

In numerous cases, individuals who are deemed suspects, yet are ultimately found to be innocent, are expeditiously absolved or eliminated from the purview of legal proceedings. The present technology is effectively adhering to the fundamental tenets of the "presumption of innocence" doctrine, which mandates that the burden of proof lies with the prosecution to establish culpability beyond a reasonable doubt.

This principle serves as the foundation for every system of criminal justice. Henceforth, it is vital to acknowledge that each individual who stands accused, regardless of their societal standing, possesses an inherent entitlement to a trial that is conducted in a manner that upholds principles of equity and justice. This legal entitlement extends its applicability even to individuals who have previously been sentenced of analogous transgressions.(T. S.-J. of Law et al.)

The entitlement to a "fair trial" emanates from the fundamental tenets of natural justice. The entitlement has furthermore attained the status of a customary principle within the realm of global and regional human rights jurisprudence.(Resolution, 2010) Moreover, numerous nations have incorporated this tenet into their

procedural legal frameworks, albeit with variations in its manifestation and implementation, contingent upon the present societal circumstances.

The principle constitutes a cornerstone within the framework of contemporary democratic systems and finds its manifestation in legal doctrines across the globe. The utilization of DNA technologies has significantly bolstered the safeguarding of the right to a fair trial, while concurrently expediting the dispensation of justice.(K. P.-U. S. L. Rev. 2013.) Professor Alec Jeffrey's invention of contemporary forensic DNA typing was employed for the first time in the UK in the 1985 Colin Pitchfork case. (R v Pitchfork, Case No: 2008/04629/ Al, EWCA Crim 963 (14 May 2009)

This was the initial criminal proceeding in the UK to employ DNA evidence, and the way the case was resolved effectively illustrated the possibilities of this technique. For the first time ever, it also showed how a little DNA sample might be applied to determine the identity of a criminal from a wide population. The Federal Bureau of Investigation (FBI) and private labs were using the technique in the US by the late 1980s.(Committee on DNA Technology in Forensic Science. The groundbreaking Colin Pitchfork case and the explosive growth of DNA technology databases strongly suggested that DNA profiling will emerge as the most significant forensic investigation technique of the 20th century.(Gill, 2005)

DNA technology became widely employed in many countries' investigation procedures in a very short period, encompassing both industrialized and developing countries.(K. P.-U. S. L. Rev. 2013.) Utilizing DNA technology, DNA profiles—which often come from specimens of human DNA—are examined. The specimens may be taken from the bodies of perpetrators or aggrieved, or from the crime sites. The next step is to examine previously recorded profiles in the DNA database with DNA profiles, or the findings of the analysis of the gathered DNA samples, to find matches. Thus, the successful completion of criminal and civil probes has been boosted by the forensic use of DNA specimens and profiles, and this procedure has already shown to be an effective means of ensuring a prompt trial and justice.(K.

P.-U. S. L. Rev. 2013.) Currently, nations are in the process of developing and augmenting human DNA databases for the purpose of utilizing them in civil and criminal investigations. These databases vary in magnitude, spanning from a modest collection of several hundred specimens to a substantial compilation of several million samples.(Simoncelli et al.)

DNA databases, consequently, serve as an exceptional repository for forensic evidence. The utilization of DNA profiling within the purview of law enforcement agencies was originally rationalized with the primary objective of identifying individuals involved in acts of sexual assault, homicide, and other abhorrent criminal activities.(Simoncelli et al..) However, over time, its application has progressively broadened to encompass individuals suspected of engaging in a diverse range of criminal behaviors. In the wake of the tragic events of September 11, 2001, law enforcement agencies across the globe have undergone significant expansion in both the scope of their investigative endeavors and the methodologies employed therein.

The rationalization for the growth and utilization of forensic DNA databases has additionally been substantiated by invoking the spectre of terrorism.(K. P.-U. S. L. Rev. 2013.) Nevertheless, it is imperative to acknowledge that the utilization of this novel technology does not come without inherent risks. The utilization of DNA profiling has the potential to unveil highly delicate data pertaining to an individual and their familial connections, thereby potentially exerting adverse effects on their well-being, unless appropriate measures are taken to safeguard against the potential misapplication, whether unintentional or intentional, of such data.(K. P.-U. S. L. Rev. 2013.) The predominant manifestation of such misapplication, leading to substantial transgressions of privacy and human rights, resides in the unlawful divulgence of delicate information pertaining to an individual's susceptibility to ailments and their lineage, for instance, which can be procured from their genetic material. Hence, it is imperative to embrace a judicious methodology in the utilisation of DNA data, thereby ensuring that the potential encroachment upon

privacy and infringement upon human rights are maintained within a permissible threshold.

Nevertheless, it is imperative to acknowledge that the forensic application of DNA data is consistently subjected to meticulous examination. This scrutiny is not solely rooted in its likely advantageous implications within the realm of justice dispensation, but also stems from the inherent peril of potential misappropriation.(K. P.-U. S. L. Rev. 2013.)

3.1. Challenges in DNA Information: Human Rights and Privacy Issues

Numerous contentions pertaining to the forensic application of DNA databases have been posited, and the majority of these contentions are intertwined with the gathering, preservation, retrieval, and use of DNA specimens that serve as the foundation for DNA profiles.(Patyn et al.) Numerous forensic DNA databases uphold the retention of DNA samples derived from diverse individuals, encompassing those who have been absolved subsequent to the culmination of legal action, cases where charges were dismissed or not pursued, or even instances where the specimens pertain to individuals who were eliminated from inquiry based on the very sample in question. When DNA samples are stored and preserved within databases, it becomes feasible to amass the utmost personal data pertaining to a person as well as their familial connections in relation to specific traits, encompassing the inclination towards certain ailments.(Williams et al.

This phenomenon arises due to the fact that genes are widely regarded as reliable indicators of numerous aspects pertaining to the human essence. These genetic markers possess the capacity to manifest human phenotypic characteristics, such as ocular pigmentation, as well as a proclivity towards specific ailments, such as cardiovascular disorders and hereditary forms of breast carcinoma. A comprehensive analysis of DNA specimens may also serve as a means to identify genetic disorders that impact cognitive abilities, such as phenylketonuria. However,

it may not always provide an accurate assessment of the extent to which a genetic disorder, such as Down Syndrome, may manifest in an individual. It may also denote a proclivity towards specific psychiatric disorders, such as schizophrenia.(S. J.-J. of Law et al.)

Certain scholars posit that deoxyribonucleic acid (DNA) harbors intricate data pertaining to an array of behavioral attributes, encompassing the inclination towards seeking exhilaration as well as a tendency for aggression. Furthermore, it is postulated that DNA may also hold indications concerning the likelihood of exhibiting violent, addictive, or criminal tendencies. Several authors and researchers, conversely, challenge the assertions posited regarding the efficacy of genetic data in prognosticating said behaviors as opposed to merely being linked to certain behaviors in specific cases, and highlight the intricate interplay between genetics and the surrounding milieu. Furthermore, it is widely acknowledged that deoxyribonucleic acid (DNA) harbors crucial data pertaining to familial lineage, commonly referred to as pedigree. The proliferation of such delicate information has elicited apprehensions regarding the safeguarding of personal and familial privacy.(S. J.-J. of Law et al.)

Moreover, the utilization of DNA profiling in the detection of an accused person has a possibility of lead law enforcement personnel to the residences of the suspect's relatives, wherein they may inquire about the nature of their genetic connection to the perpetrator as well as their location during the commission of the offence.(Tech., 2010) A particularly noteworthy encroachment upon personal privacy manifests when law enforcement entities engage in direct interrogation of familial individuals associated with a suspect, frequently with the intention of procuring their deoxyribonucleic acid (DNA) samples.(Tech., 2010)

This phenomenon possesses evident societal as well as practical ramifications. For example, it has the potential to detrimentally impact an individual's matrimonial union, disrupt their professional trajectory, or even irreparably devastate their entire

existence. The employment of DNA in criminal investigations and judicial proceedings holds significant importance. However, it is imperative to acknowledge that both law enforcement agencies and the courts often fail to comprehensively address the complete magnitude of privacy risks associated with DNA profiling. Moreover, the act of procuring specimens of DNA from individuals without their consent or under coercion poses a potential jeopardy to their physical well-being and bodily autonomy.(Williams et al.) The potential future utilization of DNA information preserved within DNA databases presents a plausible peril to the physical well-being and hereditary confidentiality. The regulations and protocols pertaining to the acquisition, inclusion, and elimination standards for DNA specimens within a database, along with the allocation and persistence of profiles within forensic DNA repositories, inherently give rise to a multitude of ethical quandaries.(Machado et al.) In a broad sense, the ethical quandaries pertaining to the acquisition of DNA data revolve primarily around the fundamental principle of 'informed consent'.(K. P.-U. S. L. Rev. 2013.)

As a result, there exists a collective of individuals, organizations, and institutions who possess an avid curiosity in acquiring pertinent and delicate data pertaining to the human anatomy.(L. H.-D. LJ, 2004) The dissemination of this delicate genetic data may potentially yield significant ramifications within familial and societal contexts. It has the potential to exert impact on placement selections made by adoption organizations or enable prospective spouses to choose their partners depending on perceived genetic superiority. It may also engender instances of prejudice and the marginalization of an individual or collectives.

Furthermore, it is worth noting that the biological data has the potential to lead to the creation of an additional societal stratum, commonly referred to as a 'genetic minority' or an underprivileged group consisting of individuals who are believed to possess genetically inferior traits. This proposition posits that based solely on biological data, society may engage in discriminatory practices against individuals considered 'inferior', submitting them to custodial arrangements or implementing

targeted eugenic interventions aimed at eradicating those whose genetic makeup exhibits the undesirable characteristic. Potential strategies that could be considered encompass the implementation of obligatory sterilization protocols for individuals within the reproductive age bracket, as well as mandatory pre-conception or pre-implantation screenings.

Additionally, the abortion of foetuses conceived with genetic traits deemed undesirable may be contemplated. This phenomenon could hypothetically transpire, albeit being a mere conjecture or potentiality, rather than an absolute certainty, that certain undesirable attributes or qualities may become apparent in said individuals.(L. H.-D. LJ, 2004) In certain jurisdictions, the consideration of human rights and privacy concerns may be disregarded in favour of emphasizing the significant utility of DNA data collection and application in upholding lawfulness and societal order.

Numerous DNA repositories across the globe uphold the practice of preserving DNA specimens, including those pertaining to individuals who have been exonerated, for a designated duration subsequent to the conclusion of the investigative process. The primary rationale underlying the perpetuation of such preservation lies in the expeditious identification and apprehension of individuals who subsequently engage in further criminal activities. The perpetual preservation of genetic information obtained from individuals under suspicion and other parties has engendered inquiries pertaining to the protection of privacy entitlements.

In *S and Marper v. the United Kingdom*, (S and Marper v United Kingdom (European Court of Human Rights, Grand Chamber) the aggrieved contended that the preservation of their deoxyribonucleic acid (DNA) samples and profiles encroached upon their entitlement to the safeguarding of their private life, as this delicate data is intrinsically connected to their individual identity. They contended that the aforementioned categories of details ought to be preserved under their authority. The application put forth by the concerned parties was turned down by

the esteemed Administrative Court, and subsequently, their appeal to the distinguished UK House of Lords was also dismissed. (S and Marper v United Kingdom (European Court of Human Rights, Grand Chamber)

Lord Steyn opined that the mere preservation of fingerprints and DNA samples does not amount to any encroachment upon the realm of personal privacy. Furthermore, he deemed such action to be commensurate with the imperative requirements of crime detection, inquiry, and subsequent legal proceedings. According to current UK legislation, there is no explicit requirement for the elimination of DNA samples. Consequently, it is permissible to retain these specimens even after their initial objective has been fulfilled., subsequent to the legal recourse to the European Court of Human Rights (ECtHR), it was determined by the Court that the comprehensive and non-discriminatory scope of authority pertaining to the preservation of fingerprints, cellular samples, and DNA profiles of individuals who are under suspicion but have not been sentenced for criminal offences, contravenes the entitlement to the preservation of privacy and familial relationships.

The formidable influence of deoxyribonucleic acid (DNA) and its associated technological advancements, along with their prospective capabilities, hold considerable weight. However, they give rise to serious inquiries that demand utmost attention and cannot be disregarded. It is imperative to contemplate the profound ethical quandaries that ensue from the utilisation of DNA profiling. The resolution of societal quandaries necessitates meticulous evaluations from an economic and legal standpoint, specifically through the lens of cost-benefit assessment. This evaluation aims to strike a delicate balance between the fundamental rights of the individual and the collective rights of society.(Shapiro et al., 1990)

The vast majority of governing bodies must acknowledge the imperative of recognizing that the scope of DNA profiling methods extends beyond the present moment, encompassing the potential insights that may be gleaned from this

technology in the foreseeable future. Nevertheless, it is essential to acknowledge that the perpetuation of state security measures remains indispensable, as they serve the paramount purpose of safeguarding the collective welfare of the populace. However, it is crucial to adopt a judicious and equitable stance in this regard.(Shapiro et al., 1990)

Safeguarding the intertwined interests of society, namely the forensic application of deoxyribonucleic acid (DNA) for the facilitation of justice and the preservation of human rights and privacy, is of utmost importance. In the realm of forensic science, the acquisition, preservation, and employment of confidential private information perpetually gives rise to ethical, societal, and legal quandaries. (Levitt, 2007) Several salient privacy concerns involve the acquisition and preservation of deoxyribonucleic acid (DNA) specimens and profiles for an indeterminate duration, particularly those procured from individuals without their explicit consent, in addition to the expansive authority and utilization of genetic samples and data by law enforcement entities.(Williams et al.)

Hence, it is contended that forensic DNA databases inherently present a privacy risk due to the intrinsic informational content encapsulated within DNA specimens. The necessity for ensuring a certain level of safeguarding personal privacy in the establishment and utilization of DNA databases is likewise widely accepted without significant debate.(Williams et al.) Since the advent of the 1990s, governmental bodies and lawmakers across the globe have grappled with the delicate task of maintaining equilibrium between two divergent yet equally consequential concerns: the implementation and utilization of DNA databases within their respective jurisdictions, and the apprehensions surrounding human rights and privacy.(Shapiro et al., 1990)

The ongoing legal and policy matter at hand pertains to the delicate equilibrium between the advantageous investigative capabilities of DNA identification and the potential encroachment upon individual privacy. This topic has engendered

persistent deliberation among both established and emerging nations worldwide. Governments, policymakers, and lawmakers across the globe are currently endeavoring to achieve a judicious and efficacious equilibrium between the potential drawbacks or encroachments and the inherent merits or efficacy of employing forensic DNA profiling and databasing.(Shapiro et al., 1990)

A well-calibrated strategy will facilitate the utilization of genetic technology advancements that promote principles of social equity and shared concerns, while concurrently ensuring an adequate assurance for the global society that these advancements are subjected to appropriate ethical examination and legal regulation.(D. W.-N. G. and Society, 2010)

An additional salient matter pertains to the extent of access that ought to be granted to law enforcement authorities with regards to DNA specimens subsequent to their preservation. In certain instances, it is plausible that the disclosure of an individual's genetic disorder or susceptibility may serve as a means to ascertain potential culprits. This scenario may arise, for instance, when law enforcement authorities are actively seeking an individual afflicted with a specific ailment. Presently, law enforcement agencies possess the authority to solicit personal genetic information from an individual's medical dossier, albeit exclusively for the purposes of averting, identifying, or litigating a grave transgression.

The extent to which the police can uphold such ethical protection also gives rise to a significant inquiry. Furthermore, the absence of a coherent laws and regulations and an inadequate oversight mechanism pertaining to the accessibility and utilization of human DNA information by external entities, including governmental bodies, represents significant challenges.(Atlantis 2003.) Furthermore, it is imperative to acknowledge the escalating expenses associated with the administration, maintenance, and retention of a substantial database encompassing millions of DNA specimens.

Consequently, it becomes imperative to undertake a comprehensive evaluation of the cost-benefit ratio through a meticulous 'cost-benefit analysis'.(Mccartney, 2004) Hence, the intricate matter at hand revolves around the delicate equilibrium between the advantages and quandaries associated with the acquisition and utilization of genetic information.

4. Challenges Encountered by Forensic Science

The forensic challenge encountered in the context of criminal adjudication is characterized by its intricate, ever-evolving nature and multifarious dimensions. It encompasses a wide range of matters and discussions pertaining to the validation, generation, presentation, testing, evaluation, and utilization of forensic science evidence within the framework of criminal proceedings. The present discourse undertakes a comprehensive examination of the evidentiary rules that regulate the admissibility of scientific evidence and expert witness testimony within the framework of common law.

Furthermore, it critically evaluates the fundamental presumptions and potential vulnerabilities inherent in the adversarial trial approach. The persuasive nature of scientific evidence is intrinsically rooted in our contemporary era characterized by scientific rationalism. Despite our purported urban complexity, we remain susceptible to succumbing to a credulous adherence to scientism, wherein any assertion labelled as "scientific" elicits nearly automatic deference.(Haack, 2011) The administration of criminal justice, in its current state, is predominantly governed by human agents, and absent the hypothetical scenario of robotic dominance, this human-centric paradigm is expected to persist. Consequently, the subjective interpretations and perspectives of individuals hold significant sway in shaping the conduct of criminal investigations, indictments, and proceedings. It would be premature to hastily disregard the importance of media coverage pertaining to forensic science, as if it were merely trivial "infotainment" extraneous to the weighty realm of criminal justice administration. Law practitioners, including

lawyers, prosecutors, and magistrates, are not impervious to the influence of prevailing societal beliefs and misunderstandings.(E. I.-T. C. L. Rev. 2010.)

Furthermore, it is important to note that in certain jurisdictions where non-experts are still responsible for determining facts in criminal cases, a practice that persists in numerous common law jurisdictions, the influence of commonly held notions and intuitive understandings of forensic science directly impact the decisions rendered by juries and magistrates. Upon thorough examination, it becomes evident that forensic science assumes a crucial position in upholding the trust of the general public in the precision and reliability of criminal convictions.

Particularly in democratic societies, this trust holds significant value as it serves as a fundamental component in establishing the normative legitimacy of criminal adjudication. Undoubtedly, it must be acknowledged that the portrayal of forensic science in media outlets does not provide an unadulterated or unaltered perspective on the intricacies of social dynamics and institutional truths. The media possesses distinct organizational objectives and agendas, just as the press offices of criminal justice institutions and government sections do.(R. E.-T. B. J. of Criminology 1991.)

The adoption of a critical stance regarding news reporting pertaining to matters of crime and justice has perennially remained imperative.(Morgan et al., 2012) Even in the preponderance of contemporary political discourse, prior to the proliferation of political manipulation, disinformation, and the dissemination of unverified claims, the digital realm was already plagued by the presence of misleading narratives, fabricated news, and the propagation of unsubstantiated information, thereby detrimentally impacting the quality of public deliberation.(Morgan et al., 2012)

These remarks pertaining to the present state of criminal justice administration merely skim the surface of what can be considered the most undervalued aspect of the "forensic challenge," which is its inherent complexity. One plausible approach

to elucidating this intricacy involves positing that forensic science amalgamates the myriad predicaments and prospects inherent in the realm of science, alongside the multifaceted challenges and possibilities that permeate the domain of criminal justice. Furthermore, this amalgamation is further compounded by the intricate task of seamlessly integrating these two domains in a successful manner, thereby amplifying the confluence of predicaments and opportunities.

However, it must be noted that the said statement is a considerable oversimplification. The true complexity of the forensic endeavor does not solely involve the amalgamation of two distinct elements, akin to the process of baking a composite entity composed of Science and Law. Rather, it necessitates the intricate integration of a myriad of constituent elements, each possessing its own unique characteristics and intricacies, in order to construct a cohesive and efficient apparatus that operates seamlessly without encountering impediments, malfunctions, or potentially fatal consequences.(S. J.-J. of Law et al.)

The field of forensic science is characterized by its lack of homogeneity, as it encompasses a diverse range of disciplines and sub-disciplines. The phrase encapsulates a broad and inclusive category encompassing various fields of knowledge and methodologies that possess the common attribute of being applicable to legal technology. However, it is important to note that these fields differ in terms of their respective methodologies, level of development, epistemic status, professional structure, institutional affiliation, and evidentiary significance.

The extent of diversity is significantly amplified when we broaden the scope of the "forensic" designation to encompass forms of expertise that may not strictly adhere to scientific principles or may only partially or subjectively do so. This includes domains such as medicine, psychiatry, psychology, and others. However, it is important to note that forensic science possesses a certain generality, terrestrial solidity, and stability that is absent in the realm of criminal justice.(S. J.-J. of Law et al.)

The intricate legal framework and operational procedures of criminal proceedings exhibit significant variations across different territorial jurisdictions, thereby engendering a distinct realm of diversity and, more notably, jurisprudential intricacy. While scientific knowledge and principles remain consistent worldwide, it is important to acknowledge that their applications in forensic science may exhibit variability. There is no innate peculiarity or cause for skepticism in the divergence of applications of scientific information across various legal systems. This is due to the fact that the evidentiary significance of forensic science is invariably influenced by the specificities of local institutional frameworks, professional norms, and procedural customs. It is not solely reliant on purely scientific principles, but rather a synthesis of multifaceted factors. In jurisdictions that adhere to the practice of trial by jury, it is imperative that even the most advanced scientific information be put forward in a manner that is understandable to lay fact finders. This is crucial in order for such knowledge to hold any forensic significance and to allow these individuals to reliably evaluate its probative value.(S. J.-J. of Law et al.)

The question if forensic science should be exclusively managed by the state or involve private entities operating within a market-based framework, as well as the degree to which forensic science facilities should be accessible to defence attorneys, can only be ascertained through a meticulous examination of jurisdiction-specific factors and in keeping with the particular local circumstances. This determination necessitates a thorough consideration of numerous legal, administrative, factors.(S. J.-J. of Law et al.)

One crucial lesson that can be derived from this scenario pertains to the utmost significance of adopting a comprehensive and all-encompassing viewpoint when considering the function of forensic science within the framework of the criminal justice system. Trials, being the focal point of media coverage and garnering significant scholarly interest, assume an even more captivating nature when they encompass courtroom proceedings characterized by intense clashes between expert

witnesses.(S. J.-J. of Law et al.) Nevertheless, it is important to acknowledge that forensic science plays a significant role in shaping the trajectory of criminal investigations, influencing the decision-making abilities of prosecutors, and informing defense attorneys' counsel to their clients regarding plea bargains.(S. J.-J. of Law et al.) A disproportionate emphasis on the significance of expert testimony during trial proceedings would inevitably overlook the majority of the forensic activities that take place within criminal legal proceedings. Similarly, while the establishment of procedural regulations to govern the acceptability and assessment of scientific evidence during legal proceedings is unquestionably a crucial legislative endeavor, the mere construction of procedural frameworks will amount to nothing more than the fabrication of illusory fortresses unless experts within the realm of criminal justice are able to consistently obtain access to dependable and superior forensic science support in practical application.

The exclusion of flawed forensic science during trial proceedings is a remedial measure that is implemented at a later stage, addressing the symptoms rather than the root cause. In contrast, a more efficacious approach would involve prophylactic measures aimed at ensuring the reliability of forensic science and expert witness testimony. This can be achieved through comprehensive training, authorization, confirmation oversight by regulators, and the cultivation of specialized cultures.(S. J.-J. of Law et al.) It is prudent to engage in a thorough investigation and comprehensive assessment of a purported problem prior to embarking upon remedial measures.

The annals of criminal justice reform throughout history are replete with instances of disillusioned hopes, unanticipated repercussions, and paradoxical outcomes, thereby resulting in the administered remedy frequently proving to be more deleterious than the ailment itself. The maxim "*Primum non nocere*!" i.e. "First do no harm" should be regarded as the guiding principle not only for physicians but also for legislators. Fortunately, there exists a considerable body of critical resources from which we can readily access in order to facilitate a well-informed

diagnostic process. The field of forensic science and the utilization of expert witness testimony have garnered a substantial and continuously growing body of interdisciplinary literary works.(J. Fraser, 2020)

5. Criticisms and Obstacles Confronted by Forensic Science

5.1. **Junk Science**(Baughman, 1992)

The term "junk science" refers to scientific research or findings that are considered to be of low quality or lacking in credibility. The forensic science technique or disciplinary specialism in question can be deemed invalid due to its inherent inability to effectively function. This lack of efficacy is primarily attributed to the tests employed within this framework, as they fail to accurately measure the intended variables they claim to assess. Consequently, the outcomes obtained from these tests do not accurately reflect the information they claim to convey.

5.2. Inaccurate Interpretive Frameworks and Untested Processes:

The validation and interpretative frameworks of forensic science strategies are currently insufficient, thereby undermining the accuracy of analytical findings and the inferential deductions derived from them.(Facey et al.)

5.3. Ineffective Administration of Evidence:

The current state of forensic laboratories and practitioners reveals a notable deficiency in the establishment of comprehensive protocols and procedures for the collection, preservation, and processing of physical samples. This deficiency hampers their ability to ensure the integrity of these samples, as they are susceptible to pollution, problematic deterioration, and other factors that may compromise the crucial chain of custody.

5.4. The Shortcomings Inherent in the Application of Scientific Methodology:

Certain tests or scientific viewpoints exhibit a deficiency in adhering to the rigorous standards of objectivity, autonomy, and fairness that are characteristic of scientific inquiry. These assessments and perspectives are particularly prone to the influence of unconscious cognitive biases.(Risinger et al.)

5.5. The Inherent Susceptibility to Error in Human Beings:

Forensic scientists and expert witnesses are prone to committing idiosyncratic errors, which may include the inadvertent input of incorrect data.

5.6. Fraudulent or Deceptive Practices:

Experts, who are purportedly knowledgeable in their respective fields, may possess corrupt tendencies or lack the necessary competence, thereby rendering them as disingenuous individuals.

5.7. Excessive Reliance on Testimonials:

Authentic specialists often venture beyond the confines of their established domain of expertise when offering forensic conclusions.

5.8. Influence of Investigative Methodologies:

The integrity of sound scientific practices is compromised by the influence of investigative methodologies and/or adversarial criminal procedures.

5.9. Legal Mismanagement:

It is widely observed that there exists a lack of comprehensive understanding of scientific principles among legal professionals and judicial bodies, leading to instances where scientific evidence is mishandled or exploited for strategic purposes.

5.10. Failed Communication:

Professionals in various fields often exhibit a certain incapacity or reluctance to effectively communicate their ideas and knowledge to individuals outside their

respective domains, whether it be through oral discourse or written expression. This deficiency in communication skills can hinder the comprehension of non-specialists, who may struggle to grasp the complex concepts and terminology employed by experts.

5.11. Lenient Criteria for Admittance:

The admission of dubious scientific evidence in court proceedings is a matter of concern, as it increases the likelihood of erroneous judgements, thereby subjecting fact finders to elevated risks of adjudicative fallacies.

5.12. Extremely Stringent and Conservative Requirements for Acceptance:

The courts frequently exhibit a propensity to expeditiously dismiss innovative or non-traditional expert viewpoints, thereby denying fact-finders access to pertinent data crucial for their decision-making processes.

5.13. Adversarial Shortfall:

Insufficient scientific substantiation is evident in the defense presented during the trial phases.

5.14. Fabricated Disagreement:

The utilization of adversarial trial procedures serves to emphasize inconsequential disparities among expert viewpoints, thereby concealing significant consensus.

5.15. Institutionally Incapable of Settling a Real Dispute:

Criminal trials, as they currently stand, prove to be inadequate platforms for the purpose of effectively resolving authentic scientific disputes.

5.16. Overly Reverent Judicial Verdict:

It has been observed that juries often encounter challenges in comprehending scientific evidence, leading to a tendency to readily rely on specialist testimony.

5.17. An Overly Skeptical Judiciary:

Juries, regrettably, exhibit a limited comprehension of scientific evidence, thereby resulting in a failure to duly acknowledge the probative worth of expert testimony.

5.18. Number-Blindness:(Schneps & Colmez, 2013)

The general populace often lacks a comprehensive understanding of the probabilistic or statistical underpinnings that form the basis of scientific evidence. Consequently, this deficiency leads to the emergence of localized iterations of both overbearing jury reservations and excessive jury deference.

5.19. Two Contrasting Cultures:

The methodological incompatibility between Law and Science renders forensic science, as the offspring of an ill-fated union between two opposing disciplines, destined to grapple with an inherently uncertain nature.(Wonder, A. K. (1989, March).

The challenges at hand exhibit a remarkable amalgamation of diverse elements. There exists a degree of overlap among certain items, thereby suggesting the potential for a reevaluation and subsequent revision of their respective limits. Moreover, it is important to note that in practical applications, analytically discrete characteristics frequently exhibit interactive properties, which could possibly exacerbate one another or, conversely, lead to the cancellation of diametric tendencies. Although varying in their degree of incisiveness and concern, the criticisms at hand are all derived from tangible instances of impropriety, errors, and miscarriages of justice. Furthermore, a multitude of official reviews and authoritative inquiries lend support to these criticisms, thereby bolstering their validity.

Undoubtedly, it is an inherent characteristic of human nature to commit errors; however, such a reality should not undermine the validity of critique as being vacuous or lacking substance. The persistent and indelible peril of human fallibility

underscores the imperative for the establishment of institutionally resilient frameworks encompassing triangulation, peer assessment, quality audit, and efficacious administration of human risk elements.

The presence of numerous contradictory challenges within this context serves as an initial indication of the extensive and persistent regulatory obstacles that forensic science presents to the criminal justice system. The feasibility of a singular regulatory approach effectively mitigating the entirety, or even a majority, of these multifaceted and somewhat conflicting concerns appears to be exceedingly improbable. The implementation of solutions to specific problems may inadvertently give rise to the emergence or intensification of additional risks or deficiencies in other areas of the system. The purported panaceas are susceptible to spurious treatments or ineffectual pharmaceutical interventions.

The persistent themes encountered in discourse surrounding the topic at hand include mutual misconceptions, communication breakdowns, and purported irrationalities within the framework of adversarial criminal procedure. The issue pertaining to traditional diagnostic approaches does not primarily stem from their lack of plausibility. Instead, it predominantly arises from the tendency of the underlying analysis to propagate shallow generalizations and misconceptions, consequently yielding inherently flawed recommendations for the improvement of institutions. Forensic science, at its core, represents an applied discipline within the realm of scientific inquiry.

Forensic science, as generally delineated, can be characterized as the scientific discipline that is employed in the realm of justice administration.(S. J.-J. of Law et al.) Its primary objective is to serve the interests of justice, as dictated by the established positive legal framework within a particular jurisdiction and is fundamentally grounded in standard political morality.(Roberts, 2014)

Forensic science, while commonly acknowledged as a collaborative endeavor between experts, law enforcement officials, advocates, and courts, must be

understood within the framework of criminal adjudication. In this context, the hierarchical structure dictates that science is subordinate to legally defined goals and principles. This ostensibly purports to unveil a deep-rooted and persistent manifestation of cultural alienation that creates a divide between the realms of Science and Law.(Roberts, 2017) However, upon closer examination, it becomes evident that this critique lacks the level of discernment and profundity that it initially presents.

Acknowledging the notable disparities in the modus operandi of lawyers and scientists, as well as their distinct cultures and professional principles, it is imperative to recognize that forensic science, at its core and in its essence, is intricately intertwined with the legal profession. In order to achieve success in accordance with its own principles, forensic science must be capable of accommodating legal and more comprehensive justice imperatives by effectively integrating scientific knowledge.

The nature of law is inherently contingent upon jurisdiction, whereas forensic science, as a scientific discipline, is not bound by such jurisdictional limitations. The variability of the worth and standard of forensic science is contingent upon contextual factors, whereby the efficacy of evidence in promoting justice is subject to variation across different jurisdictions and cases. The ubiquitous awareness of institutional context poses a significant risk of transforming any normative generalization regarding forensic science or other forms of expert evidence into an untenable dogma. Various forms of expert evidence, including the testimonies of individuals possessing expertise in fields such as astrology or magic, may potentially hold relevance and possess epistemic justification within the context of criminal proceedings.(S. J.-J. of Law et al.)

The extent of their relevance and justification is contingent upon the specific inquiries they address and the particular purposes for which they are employed. The statement underscores a significant subject matter pertaining to conceptual

taxonomy, which exerts a profound impact on the process of legal reasoning. The regulatory framework pertaining to evidence in common law jurisdictions typically operates within the confines of a homogeneous understanding of "expert evidence." In the realm of English law, it is worth noting that there exists no explicit acknowledgment of a distinct subdivision pertaining to "forensic science evidence," and the legal framework does not directly engage with this category.

When faced with the notable variation in disciplinary backgrounds within the field of forensic science and other areas of expertise, one may be inclined to believe that specific types of expert evidence should ideally be subject to individually tailored legal regulations that are adapted to their respective contexts. However, the feasibility of this approach hinges upon the ability to establish functionally sound differentiations among various forms of expert evidence, thereby delineating distinct domains of methodologically interconnected specializations. The most tenable categorization lies in the dichotomy between "scientific" and "non-scientific" domains of expertise. Nevertheless, the empirical evidence from the United States suggests that the distinction between science and non-science does not necessarily provide a more lucid understanding or reduce the potential for disagreement when compared to the conventional expert/non-expert dichotomy employed in common law systems.(Roberts, 2017) The prevailing notion within English law continues to be centered around the term "expert," as opposed to "science" or any other approach that purports to possess comparable methodological rigor. (R. v Luttrell [2004] 2 Cr App R 31)

This approach confers upon the legal regulations a heightened extent of coverage and inclusiveness. It allows for the incorporation of a wide array of subject matter and substance within expert evidence, as long as it pertains to a contentious factual matter under consideration in the legal proceedings. The utilization of a generic approach necessitates the formulation of rules that possess a considerable degree of abstraction. Consequently, the application of said rules to a specific case often

demands a substantial amount of interpretational exertion in order to contextualize them appropriately.

In accordance with the established principles of orthodox common law theory, it is deemed permissible to introduce expert evidence as an exception to the general rule governing the admissibility of opinion evidence. Nevertheless, it is imperative to acknowledge that this particular assertion is not only unconstructive, but also possesses the potential to be deceptive due to its reliance on a formalistic canard. The statement posits the existence of a definitive demarcation between "facts" and "opinions," whereas in actuality, there exists a spectrum characterized by varying degrees of specificity in the explication of factual deductions derived from empirical evidence and subjective interpretations.(R. G.-Hous. L. Rev. 2008.) Similar to other forms of evidence, expert witness testimony, such as the chemical analysis of suspected narcotics, can be positioned closer to the objective "factual" end of the spectrum. Conversely, other types of testimony, like a medical diagnosis or an evaluation of the likelihood and duration of secondary transmission of physical traces, tend to reside closer to the subjective "opinionated" end. It is reasonable to anticipate a consensus among bona fide experts with regards to matters of scientific fact, while it is not uncommon for genuine divergences of perspective to manifest among specialists.(S. J.-J. of Law et al.)

However, it can be argued that scientific facts can be defined as the subjects on which authoritative specialists reach a consensus, while opinions encompass the potential for well-intentioned divergences among experts. The contrast between fact and opinion holds no greater foundational or conceptual strength within this context than the difference between experts and non-experts. In essence, it can be argued that there lacks a distinct and objective standard by which to impartially discern the demarcation between information and subjective viewpoints, as this distinction is primarily shaped and influenced by institutional constructs.(S. J.-J. of Law et al..)

Positive law delineates the substantive "matters" for criminal litigation through two separate and complementary means. Initially, it is imperative to acknowledge that substantive criminal law serves the purpose of delineating the constituent components of criminal offences, which necessitate evidentiary substantiation to attain a sentence. Concurrently, it encompasses overarching principles pertaining to responsibility, excuse, and justification. There exist notable variations in the intricate nuances of substantive criminal liability boundaries across diverse legal jurisdictions.(Simester, A. P., Spencer, J. R., Stark, F., Sullivan.) Furthermore, the specific issues that arise in criminal trials are further delineated by the interplay of criminal procedure law, which encompasses rules governing the admissibility and exclusion of evidence, local customs and practices, and the forensic strategies employed by individual litigants. The variability and impact of local legal traditions on the reach and content of substantive criminal law are comparatively less pronounced when compared to the numerous and impacted contingent elements of procedure and practice.(Simester, A. P., Spencer, J. R., Stark, F., Sullivan.)

The theoretical framework of adversarialism operates under the assumption that the prosecution's argument, which includes any expert testimony that the prosecution intends to present in response, will be subject to thorough assessment and robust cross-examination by the defence. This dynamic adds an element of interest to critiques concerning the "adversarial deficit." For defence lawyers to effectively assess the merits and drawbacks of scientific evidence presented by the prosecution, it is imperative that they possess the ability to engage the services of proficient scientific advisors.

Without access to such knowledgeable experts, defense lawyers may find themselves lacking the necessary information to carry out a comprehensive examination. Systems of criminal adjudication that lean towards being less adversarial, often referred to as "inquisitorial" systems, exhibit a preference for eschewing courtroom obstacles pertaining to scientific evidence. Instead, these

structures rely predominantly on unchallenged evidence and guidance provided by experts designated by the court.(Criminal, 2017.)

The approach employed in this manner of proceeding effectively anticipates and mitigates certain widely recognized challenges, such as the potential for criticisms driven by adversarial distortion. However, it also has the tendency to generate or intensify problems that mirror those being addressed. Concerns have been raised by local commentators regarding the propensity of judges with an inquisitorial mindset to excessively rely on the conventional viewpoints put forth by highly qualified experts. This inclination, in turn, may lead to a lack of thorough scrutiny of said opinions, thereby posing a potential threat of unjust outcomes.(Vuille, 2013)

Various competing procedural models offer a range of reform options, yet it is important to note that there are no miraculous solutions or universal remedies. The examination of divergences between the "adversarial" and "inquisitorial" procedural frameworks constitutes merely a singular dimension within the broader scope of comparative analysis. Significant disparities can be observed in the realm of criminal procedure when comparing the procedural frameworks of the "adversarial" and "inquisitorial" systems.(Roberts & Hunter, 2012)

It is a widely observed phenomenon that civil law and criminal adjudication often exhibit significant disparities in their procedural and substantive aspects, despite being administered within the confines of the same territorial jurisdiction. The sufficiency of expert evidence for a particular legal context, such as family proceedings, may not meet the criteria for admissibility in a criminal trial. This discrepancy can be attributed to the more rigorous fair trial and due process standards, as well as the elevated burden of proof that is characteristic of criminal proceedings. The consideration of mundane institutional facts should not be disregarded when engaging in comparative modelling.(Roberts & Hunter, 2012)

The rule of legal assistance for defence expertise in India has consistently appeared inadequate. In this context, it is imperative to acknowledge that publicly financed

defence forensics in Indian criminal proceedings have recently encountered the jarring impact of fiscal constraints. It is crucial to refrain from indulging in self-congratulatory contentment in light of this situation.(P. G.-C. L. Rev., 2004) In light of the imminent reduction in funding allocated to legal aid, criminal lawyers and advocates have orchestrated an unparalleled series of courtroom walkouts and days of action.

The potential diminishment of our esteemed criminal justice system is an inevitable consequence if we, as a collective society and political entity, fail to demonstrate the necessary willingness to allocate the requisite financial resources.(P. G.-C. L. Rev., 2004) Criminal adjudication, unlike the upkeep of roads, lighting for streets, does not fall under the category of “public service". In situations where the government may declare a shortage of funds, thereby restricting access to services, criminal adjudication does not align with this paradigm.

The normative limitations imposed by principles of justice, in conjunction with the legal frameworks of English common law and European human rights law, prohibit us from articulating to the defendant that due to financial constraints, we are unable to provide you with a fair trial, thus we are instead subjecting you to an unjust one.

The conventional paradigms pertaining to legal jurisdiction are exhibiting signs of strain in light of the burgeoning influence of globalization and the emergence of cosmopolitan jurisprudence.(Inquiry 2012.) In contemporary times, it is evident that the field of law exhibits a distinct propensity for traversing geographical boundaries, actively participating in transnational dialogues. As law exerts its influence upon the various locales it faces, it inevitably undergoes reciprocal transformations, adapting itself to the cosmopolitan institutional and cross-cultural encounters it experiences.(Inquiry 2012.)

Law reformists, just like practitioners, are required to actively participate in ever-changing legal landscapes, wherein the authority of states to enact and enforce laws has been restricted due to global political, economic, and social influences. The

field of forensic science, as an illustrative example, is presently subjected to various facets of pan-European rules and cross-border collaboration.(Biedermann et al., 2017) While it is important to acknowledge the legal and practical implications of these advancements, it is crucial to note that contemporary criminal law continues to primarily operate within a national or state framework, with territorial authority maintaining its utmost importance.

The regulation of forensic science evidence, including its generation, admissibility, and applications, remains primarily under the jurisdiction of national courts. This underscores the importance, within the context of our current discourse, of fundamental methodological principles in contemporary comparative law research. It is imperative to exercise caution when attempting to draw broad conclusions based on idiosyncrasies observed within specific legal frameworks, as well as when making casual extrapolations across different legal jurisdictions.(Biedermann et al., 2017)

Such actions disregard the potential existence of substantial procedural, cultural, or practical disparities that may significantly impact the validity and applicability of such generalizations. In the context of criminal trials, it is imperative to acknowledge the admissibility of expert evidence, encompassing both factual and opinion-based testimony. Such evidence is deemed acceptable when it satisfies two fundamental criteria: relevance and utility in aiding the fact-finder in fulfilling its adjudicative duties. The inclusion of ineffective expert testimony can be deemed superfluous at its most favorable interpretation, and possibly more detrimental than beneficial. This is due to its propensity to introduce confusion to the matter at hand and unnecessarily burden the legal process with preventable litigation expenses.(S. J.-J. of Law et al.)

The presented evidence is deemed inadmissible, not only within the legal framework, but also as a direct extension of fundamental principles of rationality. The concept of "helpfulness" is a subjective criterion that necessitates a nuanced

and context-dependent approach for its assessment. Trial judges are occasionally tasked with the responsibility of making intricate decisions, wherein they must carefully assess the expected evidentiary worth in settling contentious matters, while also considering the likelihood of confusion, deception, or diversion that said evidence may bring forth.(S. J.-J. of Law et al.)

Moreover, it should be noted that individual assessments of admissibility, even when affirmed through the appeals process, do not generally hold the status of formal legal precedents. Rather, they represent specific instances where established legal principles have been applied within a particular context.(Redmayne et al., 2011) An additional, cumulative doctrinal requirement for the admissibility of evidence is the need that said evidence be presented by a bona fide expert who possesses the necessary qualifications. In the absence of the witness possessing the necessary legal competence as an expert, there would be a dearth of justifiable grounds to accord her testimony with the status of being legally binding or accurate. The evaluative criterion employed by English law to determine expertise is substantive in nature, rather than formal. It is of no importance how, when, where, or why an individual has acquired their expertise, as long as they possess the pertinent specialist skills or expertise. (R. v. Silverlock [1894] 2 QB 766, CCR)

The acquisition of knowledge, skill development, and the attainment of recognized credentials can serve as indicators of expertise, yet it is important to note that they do not invariably constitute prerequisites. An instance may be presented wherein an individual, deemed an expert, has potentially attained an exceptional level of proficiency in the art of lip-reading (R. v. Luttrell [2004] 2 Cr App R 31, CA) or the practice of interpreting foreign languages, (R. v. 0 [2010] EWCA Crim 2985) without having procured any official credentials or qualifications. Nevertheless, it is worth noting that certain domains within the realm of forensic science or other specialized fields may necessitate the acquisition of knowledge and skills exclusively through structured education or official recognition.

Consequently, this circumstance can potentially give rise to pragmatic impediments in guaranteeing the accessibility of appropriately qualified professionals who can effectively aid both the prosecution and defence in the context of adversarial criminal litigation. Due to a dearth of discipline-specific forensic science acumen, the majority of trial judges find themselves inadequately equipped to evaluate the proficiency of expert witnesses.(S. J.-J. of Law et al.)

Invariably, it is common for individuals to resort to proxies, such as educational background, credentials, work history, and affiliation with pertinent professional and scholarly organizations, in order to ascertain the authenticity and expertise of witnesses who have been directed by a specific party. The presence of a structural epistemic reliance gives rise to the potential for extensively documented instances of forensic abuses, particularly those involving charlatanism and excessive overreach.(S. J.-J. of Law et al.)

The rational motivation for law enforcement agencies, who are themselves operating within stringent financial limitations, is to minimize the utilization of scientific assistance whenever possible like in situations where the police can obtain a confession without relying on scientific evidence. Furthermore, in other instances, they seek to reduce expenses by procuring only the essential forensic services necessary to further accomplish strategic goals in the investigation.(P. G.-Va. J. Soc. P. & L. 1996.) The market incentives in question do not appear to possess an inherent capacity to reliably generate truthful outcomes within the context of criminal adjudication.

In accordance with the principles of market logic, it is imperative to question the rationale behind law enforcement agencies allocating their budgets towards scientific tests, unless the expected outcomes possess a higher probability of furthering the progress of the investigation as opposed to aiding the defence. The practice of conducting scientific research internally, within an organization, is prone to diminishing standards and poses a significant risk in intensifying

confirmation bias during the process of scientific experimentation and the subsequent reporting of results.(S. J.-J. of Law et al.)

As is readily apparent from the previously discussed discourse, the concept of "the forensic challenge" is not merely a singular issue or agenda of the government, but rather a conglomeration of interconnected institutional obstacles pertaining to the delivery, authentication, governance, elucidation, demonstration, examination, and assessment of forensic science services, evidentiary materials, and testimonial declarations. The intricate nature of forensic science can be attributed to its diverse subject matter and multifaceted institutional roles and implementation. This complexity significantly contributes to the legislative, administrative, and policy-making difficulties that are intertwined with the field.(S. J.-J. of Law et al.)

6. Confronting the Challenges

The integration of forensic science into the administration of criminal justice necessitates a comprehensive strategy encompassing the organization, regulation, and efficient utilization of forensic science services, as previously observed. In the majority, if not the entirety, of present-day criminal justice systems, the involvement of forensic science in criminal inquiries, legal actions, and pre-trial procedures tends to hold greater significance - particularly in terms of overall caseload - compared to its more conspicuous and frequently sensationalized influence on disputed criminal trials.(S. J.-J. of Law et al.) The subject matter at hand pertains to the inquiries surrounding regulatory policy, which necessitate a coherent response from each legal jurisdiction in accordance with their respective normative obligations and procedural practices. These inquiries encompass crucial aspects such as the organization, funding, validation, and regulation of a comprehensive array of forensic science services of high caliber. Additionally, they involve deliberations on whether and how to certify proficient experts, as well as determining whether forensic science should be regarded as a responsibility of the

public sector or if reliance on market forces and private enterprise should be considered to some degree.(S. J.-J. of Law et al.)

Furthermore, it should be noted that the examination of admissibility does not fully encompass the range of evidentiary concerns that arise in relation to forensic science evidence or expert witness testimony in a broader sense. Once evidence has been duly acknowledged into the context of a criminal trial, the subsequent inquiry arises as to the appropriate course of action for the individual tasked with analyzing said evidence. What is the credibility of the subject matter? In what manner does it pertain to the disputed matters and establish connections with other evidentiary elements within the case? The preceding inquiries pertain to the jury's deliberations during trials on indictment, wherein the precise reasoning behind a given jury's verdict remains elusive.

However, it should be noted that judges are not solely reliant on their own faculties when it comes to the interpretation and evaluation of evidence. According to enduring convention, trial judges are responsible for providing a comprehensive overview of the factual circumstances, as well as the pertinent legal principles. Contrary to the commonly perceived "umpireal model" of judging prevalent in adversarial trials, trial judges typically assume a more proactive role in trial administration. Academic scholars dedicate significant amounts of time and effort towards the development of progressively intricate synopses, providing guidance, and to some extent, imparting instruction to juries on how they ought to contemplate or employ specific types of evidence. Infamously erroneous or "prejudicial" inductive logic is specifically highlighted for cautionary measures and recollections in alignment with an array of "forensic reasoning rules."(Roberts & Roberts.)

Numerous customized admonitions and instructions are specifically applicable to the domain of expert evidence, particularly with regard to various facets of DNA profiling.(Redmayne, 2001) The establishment of admissibility doctrines serves to

provide an organized structure for the inclusion of scientific and other expert evidence in criminal proceedings. However, it is often necessary to provide additional functional direction to aid lawyers, judges, and fact-finders in the interpretation of scientific findings and the assessment of their evidentiary value within the context of the ongoing court proceedings.(S. J.-J. of Law et al.)

The forensic science community has recently faced significant criticism of considerable magnitude. The reason for this comprehensive examination is characterized by its multifaceted nature. However, the primary responsibility for this phenomenon can be attributed to two distinct circumstances. Firstly, the proliferation of issues and scandals within crime laboratories. Secondly, the DNA acquittal that have arisen due to the utilisation of unvalidated forensic technology, the inappropriate application of forensic evidence beyond its scientific boundaries, or the dissemination of overstated testimony by forensic analysts.(C. C.-Tex. W. L. Rev. 2010.)

In relation to crime laboratories, a considerable body of evidence has emerged in the past decade, which suggests that public crime laboratories do not possess the anticipated level of scientific integrity. Moreover, it has become apparent that these laboratories suffer from insufficient financial resources, staffing, and regulatory oversight.(C. C.-Tex. W. L. Rev. 2010.) These mentioned variables exert a substantial influence on the probability of shortcuts being taken and the concomitant restriction of research activities.

The utilization of shortcuts within various contexts has been found to be a contributing factor to the occurrence of scandals and the emergence of issues related to evidence processing. Furthermore, it has been observed that the existing body of research in these domains remains fairly sparse, thereby leading to the propagation of exaggerated assertions pertaining to the levels of credibility, dependability, and infallibility that can be attributed to certain practices or methodologies.(C. C.-Tex. W. L. Rev. 2010.)

As of the present time, a total of 272 instances of DNA acquittal have been documented,(Innocence Project.) alongside an indeterminate number of non-DNA exonerations. In the initial 200 instances of DNA exonerations, it was observed that approximately 60% of the cases were influenced by the presence of unverified or inadequate forensic science testimonies.(Garrett et al., 2009) Among the initial 225 instances of DNA exonerations, it has been observed that a significant proportion exceeding 50% were characterized by the presence of unverified or inappropriate forensic science testimony.(Risinger et al.

Several instances of wrongful convictions have been documented, some of which have even employed DNA evidence.(Risinger et al.) DNA evidence is widely regarded as the pinnacle of forensic science by many experts in the field. The issues pertaining to crime laboratory deficiencies and the subsequent occurrence of wrongful convictions have garnered significant focus from the judicial system of the nation. Significant advancements are imperative within the field of forensic science in order to augment the capacity of law enforcement agencies to accurately ascertain the guilt or innocence of individuals implicated in criminal activities. Furthermore, such progress is essential to mitigate the potential for wrongful convictions or acquittals within the criminal justice system.(Council & Engineering, 2009)

In essence, the current body of research has yet to establish the veracity of numerous fields of study within the realm of forensic science. Moreover, the discipline of forensic science exhibits a notable lack of integration with the research endeavors conducted within academic institutions. The present state of affairs, as described, elicits a sense of discouragement, as it markedly amplifies the probability of inequities and instances where justice is not served. However, it prompts an inquiry into the underlying reasons for the limited validation of forensic disciplines and the scarcity of individuals possessing a Ph.D. in forensic science.

The response to the inquiry is inherently complex, as it encompasses various facets. However, it is pertinent to highlight two primary factors that serve as a robust foundation for further analysis: insufficiency in financial resources and a dearth of stringent regulatory supervision by the governing authorities. In the realm of financial resources, forensic science frequently encounters competition from other priorities within the domain of law enforcement, resulting in insufficient funding to address the following areas:(J. Fraser, 2020)

1. the establishment of exceptional undergraduate and graduate programs in forensic science at academic institutions.
2. the recruitment of a sufficient percentage of forensic scientists to enable the successful, productive, and accurate processing of the escalating volume of forensic testing demands within our nation’s crime laboratories.
3. the modernization of our nation's public crime laboratories through the incorporation of the most contemporary and cutting-edge technologies; and
4. the undertaking of rigorous research endeavors and the development of novel techniques that can contribute to the advancement of the dual objectives of the criminal justice system, namely safeguarding the innocent and identifying and penalizing the culpable parties.

In the realm of monitoring, it is noteworthy to observe that forensic science has hitherto not been mandated to subject itself to any external governing body, but rather remains accountable solely to its own internal mechanisms. In contrast to the stringent regulations governing testing facilities, the oversight of our nation's crime laboratories and forensic professionals lacks the robust framework of effective union or state laws and agencies dedicated to guaranteeing the production of reliable and verifiable outcomes. The absence of proper supervision has resulted in the establishment of a forensic science sector that, on a nationwide scale, exhibits the following deficiencies:(J. Fraser, 2020)

1. the absence of standardized protocols for numerous forensic identification methodologies.
2. the lack of consistency in certifying forensic professionals and accrediting crime laboratories; and
3. the absence of an authoritative body capable of effectively investigating allegations of recklessness, inadequacy, or wrongdoing.

Should legislators exhibit a reluctance to adequately allocate resources and exercise effective supervision over the forensic science community, the pursuit of truth within the criminal justice system will persistently face impediments. The deleterious consequences of this phenomenon extend beyond the direct harm inflicted upon individuals who are erroneously entwined as a result of unverified forensic evidence or flawed forensic testimony. Indeed, it exacerbates the suffering experienced by the victims themselves and their respective familial units, thereby compounding the overall impact of such misjudgments.

For far too long, forensic science has not received enough funding. The vast proportion of police department labs are underequipped and require highly qualified staff who can operate the cutting-edge technology that the science sector is now developing and producing. The utilization of forensic science within the criminal justice system has experienced a substantial surge in recent years. However, it is worth noting that the allocation of financial resources towards forensic science has not witnessed a commensurate increase.(Roberts, 2014)

The imperative for sufficient financial resources arises from the presence of a budgetary predicament that is prevalent across numerous forensic services programs. The current state of laboratory financing has failed to keep pace with the escalating demands. Within the forensic science community, a multitude of skilled and committed individuals exist; however, their ability to effectively carry out their work is frequently hindered due to insufficient resources, inadequate regulations, and a lack of comprehensive national backing.(Roberts, 2014)

The augmentation of financial resources will effectively facilitate the attainment of a minimum of three distinct objectives. Initially, it will enable forensic service providers to contemporize their infrastructures and expand their workforce by recruiting additional forensic analysts. Furthermore, this initiative holds the potential to enhance the quality of both graduate and undergraduate forensic science education. Moreover, this phenomenon will undoubtedly engender a proliferation of research prospects within the realm of forensic science.

To effectively and proficiently carry out their responsibilities, it is imperative that public crime laboratories possess cutting-edge technological resources and a sufficient workforce. The acquisition of contemporary technological advancements and the recruitment of additional analysts entails a substantial financial cost.(Coverdell, 2005) In essence, the failure of legislators to augment financial resources allocated towards the modernization of public crime laboratories will inevitably impede the capacity of these institutions to carry out precise and systematic forensic examinations. Consequently, this dearth of resources will result in a multitude of adverse consequences, including the perpetration of injustices and the squandering of possibilities to administer justice effectively.(Coverdell, 2005)

The subject of modernization has emerged as a prominent concern within the realm of crime laboratories; however, it is vital to acknowledge that an even more pressing challenge lies in the realm of human resources and personnel matters. When the requirement for amenities surpasses the capacity of a supplier of services to effectively analyze the evidence that has been submitted, it leads to the occurrence of backlogs. Insufficient financial resources exert a detrimental impact on the workforce, manifesting itself in no less than two distinct manners. Initially, it is crucial to acknowledge that crime research facilities are confronted with a notable challenge in their endeavor to recruit an adequate number of experts capable of effectively managing the escalating influx of forensic testing demands.(Dale, W. M., & Becker, W. S. (2003).

Furthermore, it is necessary to acknowledge that insufficient funding within an organization inevitably culminates in the provision of unsatisfactory wages for its employees. This, in turn, causes a substantial increase in turnover rates within said organization. The phenomenon of understaffing fosters a subsequent occurrence of backlogs, which in turn gives rise to augmented caseloads, thereby perpetuating the existence of larger backlogs. The prevailing conditions serve to augment the probability that expedient measures and errors will persistently manifest.(Dale, W. M., & Becker, W. S. (2003).

A considerable proportion of diligent and dedicated forensic analysts employed within the crime laboratories of our nation exhibit deficiencies in their training and education pertaining to the biological sciences, the scientific method, and statistical analysis. Insufficient training in scientific research not only amplifies the probability of inaccuracies but also impedes the execution and appropriate assessment of empirical research within the realm of forensic sciences.(UCRLJ 2006.)

7. A Correlation Between Forensic Science and Unlawful Indictments

The concept of wrongful conviction pertains to the indictment of an individual who is factually innocent. This occurs when an erroneous identification is made, leading to the wrongful attribution of guilt to an individual for a crime that was perpetrated by another party. Furthermore, wrongful conviction may also arise in cases where no criminal activity took place, yet an individual is unjustly held accountable for such non-existent wrongdoing.(Bonventre, 2021)

Wrongful indictments engender a plethora of deleterious consequences, encompassing mental, sentimental, and financial afflictions, which are inflicted upon the individuals erroneously found guilty of offences they did not perpetrate.(Campbell & Denov, 2004) In addition to their primary consequences, these actions also generate adverse social ramifications. They destroy the familial bonds of the initial victims, potentially eroding interpersonal relationships.

Furthermore, they have the potential to diminish public confidence in our justice systems, thereby exacerbating the detrimental effects. Moreover, such actions may inadvertently subject innocent individuals to victimization by the actual criminals who continue to evade legal repercussions.(Campbell & Denov, 2004)

Wrongful indictments have been found to exhibit a correlation with a number of prevalent variables, namely, a mistaken identification of eyewitnesses, instances of false confessions, challenges pertaining to forensic science, deficiencies in the provision of legal representation, reliance on informants, instances of false testimony, and acts of official misconduct. The inclusion of forensic science within this compilation of correlates serves to illuminate the intricate interplay it shares with instances of wrongful convictions.

DNA evidence has emerged as a formidable instrument in assuaging doubts surrounding the conviction of individuals who are factually innocent within the realm of justice systems.(Gross et al., 1989) However, an examination of exonerations resulting from wrongful convictions reveals that forensic science also plays a role in facilitating these erroneous consequences.(Gross et al., 1989)

The investigation into instances of erroneous convictions and the field of forensic science has been the subject of scholarly exploration across a diverse range of academic disciplines, encompassing legal research, social psychology, science and technology studies, and the field of forensic science itself. This comprehensive overview elucidates various standpoints from various disciplines regarding the manner in which forensic science substantiates wrongful convictions. Furthermore, it contemplates recent endeavors aimed at mitigating the involvement of forensic science in perpetuating wrongful convictions.(S. C.-N. Eng. L. Rev. 2011.)

8. Innocent Project

The identification and monitoring of wrongful sentences is accomplished by researchers through the quantification of exonerations. Exoneration refers to the

formal vindication of an individual who has been convicted of a crime, wherein compelling evidence of their innocence is presented and acknowledged. In the United States, it is worth noting that the two prominent entities responsible for the compilation of exoneration data at the national level are the Innocence Project and the National Registry of Exonerations (NRE).(Innocence Project.)

The Innocence Project was established at Cardozo Law School in 1992 by attorneys Barry Scheck and Peter Neufeld. The organization is dedicated to the provision of legal advocacy services with the aim of exonerating individuals who have been wrongly sentenced. This is achieved through the utilization of postconviction DNA testing. Additionally, the organization actively engages in advocacy efforts pertaining to criminal justice policy reform.(Innocence Project.)

The NRE, which stands for National Research Entity, was established in the year 2012 and presently operates as an initiative under the auspices of the esteemed Newkirk Centre for Science and Society at the University of California Irvine, in conjunction with the University of Michigan Law School and Michigan State University College of Law. The National Registry of Exonerations (NRE) undertakes the comprehensive compilation and meticulous analysis of data pertaining to all documented instances of exoneration that have transpired from the year 1989 up until the present time.(S. C.-N. Eng. L. Rev. 2011.)

To be deemed eligible for inclusion within the National Registry of Exonerations (NRE) database, an exoneration must be predicated upon an authoritative proclamation of the individual's innocence with respect to the committed offence, or alternatively, the individual must have obtained official absolution from any and all legal ramifications associated with said offence as a result of compelling evidence substantiating their innocence.(S. C.-N. Eng. L. Rev. 2011.) Illustrative instances of such formalized measures encompass executive clemency, absolution, or dismissals predicated upon substantiated indications of an individual's innocence.

An exoneree can be defined as an individual who has undergone the process of being convicted for a criminal offence, only to subsequently receive an official declaration of innocence or be absolved of all legal ramifications associated with the conviction.(S. C.-N. Eng. L. Rev. 2011.) This exoneration is typically prompted by the emergence of evidence that establishes the individual's innocence, which was not initially presented during the trial and necessitates a reevaluation of the case. As of July 2020, it has been observed that the employment of postconviction DNA testing has resulted in the exoneration of more than 360 individuals within the territorial boundaries of the United States.(S. C.-N. Eng. L. Rev. 2011.)

Like other human endeavors, forensic science is subject to inherent fallibility. The surge in criminal activities during the 1970s was concomitant with a notable expansion in the proliferation of crime laboratories across the United States.(Peterson et al., 2007) Although the expansion was deemed imperative, it occurred in an unsupervised manner and lacked explicit direction from, or compliance with, established national benchmarks. Hence, it is evident that as the provision of crime-laboratory services witnessed growth, a corresponding increase in the prevalence of inherent issues pertaining to quality certainty and adherence to minimum scientific norms became apparent.

Based on the analysis conducted by, utilizing the data furnished by the esteemed Innocence Project, it has been determined that a significant proportion of the 86 DNA exonerations examined were attributable to errors in forensic science testing, accounting for approximately 63% of the cases. Furthermore, it has been ascertained that a notable percentage, specifically 27%, of these exonerations were a result of erroneous or deceiving testament given by forensic scientists.(Saks et al., 2005)

The examination of the initial 200 instances of DNA exonerations revealed that a significant majority, approximately 57% of the individuals who were exonerated, had been wrongfully convicted based on forensic evidence. This evidence primarily

consisted of serological analysis and microscopic hair comparison.(B. G.-Colum. L. Rev. 2008.) A comprehensive examination of DNA exonerations spanning the years 1989 to 2014 has revealed that the erroneous utilization of forensic science played a significant role in 47% of the 325 instances that were subjected to scrutiny.(West et al., 1989)

The study elucidated the improper use of forensic science, encompassing scientific error, exaggeration, recklessness, or misconduct. However, it is important to note that cases wherein forensic science was appropriately employed were not considered within the purview of this investigation.(West et al., 1989)

Nevertheless, upon thorough examination of both DNA and non-DNA exonerations collectively, the ostensible influence of forensic science diminishes. The present definition of false or misleading forensic evidence, as posited by researchers at the NRE, encompasses situations wherein a conviction is predicated, at least partially, upon forensic information that satisfies one or more of the following criteria:

1. it is a consequence of errors occurring during the process of forensic testing,
2. it relies upon methods that lack reliability or have not been sufficiently validated,
3. it is conveyed with an excessive degree of confidence that is both deceiving and overstated, or
4. It is intentionally deceptive and fraudulent in nature.

The present study's findings are subject to constraints. Initially, it is imperative to acknowledge that while the examination of exonerations has undoubtedly propelled our comprehension of the elements that contribute to erroneous convictions, it is crucial to recognize that the documented instances may not inherently epitomize the entirety of wrongful convictions.(West et al., 1989) The DNA exonerations predominantly encompass instances of sexual assault and murder, thereby rendering the dataset not reflective of criminal cases at large.(Garrett et al., 2009b)

The prevalence of certain case types in DNA exonerations can be attributed to the logical connection between the presence of biological evidence and the nature of violent offences, particularly sexual assaults and homicides.(Roman et al., 2009) Hence, it is noteworthy to observe that the variables that contribute exhibit varying degrees of disparity between DNA exonerations and exonerations in a broader context, encompassing a wider spectrum of criminal categories. Furthermore, it is imperative to acknowledge that the occurrence of wrongful convictions is a complex phenomenon influenced by a multitude of factors. Consequently, it becomes arduous to assert, from a scientific standpoint, that any specific correlate can be attributed as the sole cause of a wrongful conviction.(Cole et al.)

The act of observing and tallying the factors that were evident during a trial is fundamentally different from determining whether a specific factor was the cause of the wrongful conviction, or even assessing the extent to which said factor influenced the actions of different actors within the criminal justice system.(Cole et al.)

LaPorte's recent analysis encompassed a comprehensive examination of 133 instances of DNA exonerations, wherein forensic science played a pivotal role. The findings of this study revealed a noteworthy observation, namely that a staggering 98% of these cases exhibited the presence of multiple supplementary elements which contributed to the ultimate outcome.(G. L.-N. I., 2018.) In conclusion, it is essential to acknowledge that throughout the course of time, an assortment of terminologies pertaining to matters within the realm of forensic science have emerged within the scholarly literature.(G. L.-N. I., 2018.) There exists a contention among certain individuals that the utilization of terms such as error-prone, terrible, junk, unreliable, or fraudulent in a sweeping manner to characterize forensic science as a causal element in wrongful convictions obfuscates the diverse array of errors or issues that are implicated.(Christensen et al., 2014) Moreover, the use of imprecise terminology may give rise to contentious debates concerning the degree

to which forensic science serves as a catalyst for erroneous convictions.(J. Collins et al., 2009)

In summary, it is imperative to acknowledge that the available evidence suggests a potential decrease in the involvement of forensic science in wrongful convictions, particularly as observed in cases of DNA exoneration. In their comprehensive examination of DNA exonerations up until the year 2014, West and Meterko conducted an analysis to discern the various elements that accounted for these cases.(P. G.-Va. J. Soc. P. & L. 1996.) Notably, their findings revealed that the inappropriate use of forensic science played a significant role in approximately 47% of the investigated cases. Furthermore, the researchers meticulously scrutinized the leading factors on a yearly basis, thereby providing a nuanced understanding of the evolving landscape of these convictions.(P. G.-Va. J. Soc. P. & L. 1996.)

According to the research conducted by West and Meterko, it was observed that the rate of misuse of forensic science decreased to 20% for convictions acquired in the year 1996 or subsequent. In the realm of DNA cases, particularly those pertaining to instances of sexual assault and murder, it is plausible to posit that this phenomenon may be attributed to the escalating utilization of DNA pretrial procedures. The potential cause can also be attributed to the diminishing operation of traditional serology techniques and hair microscopy methodologies.(P. G.-Va. J. Soc. P. L. & 1996.)

The said disciplines, accounting for 55% and 47% of the total, respectively, emerged as the primary contributors in the context of the 154 DNA exonerations where the inappropriate use of forensic science was identified.(P. G.-Va. J. Soc. P. & L. 1996.)

Certain analysts have posited that the mere act of disclosing the proportion of exonerations wherein forensic science evidence was introduced during trial may inadvertently lead to an inflated understanding regarding the degree to which forensic science plays a role in erroneous indictments.(C. C.-Tex. W. L. Rev. 2010.)

While it is indeed accurate to assert that the mere existence of forensic science evidence during a trial does not automatically imply the existence of any flaws within said evidence, a thorough examination of forensic science testimonies does appear to suggest the existence of certain issues.(Schneps & Colmez, 2013)

In order to enhance comprehension pertaining to the significance of forensic science within the context of erroneous indictments, Garrett and Neufeld undertook a comprehensive analysis of trial testimonies in cases involving DNA exoneration. The primary objective of this investigation was to ascertain the veracity and reliability of the assertions provided by forensic analysts during these trials.(Schneps & Colmez, 2013)

The researchers discovered that within the sample of 137 trial records, a notable 60% exhibited instances of "invalid testimony". This term encompasses instances where the analysts' testimonies contained inferences that either misrepresented the empirical data or lacked any substantial support from empirical data.(Schneps & Colmez, 2013)

The illustrations provided encompass a range of analytical practices that involve the interpretation of nonprobative evidence as inculpatory, the disregard of exculpatory evidence, the presentation of erroneous statistics, and other similar instances. The authors observed that the majority of cases examined in the study set pertained to sexual assault, wherein biological evidence, such as serology and microscopic hair comparison, was routinely acquired. Consequently, the invalid testimony primarily manifested in these specific types of cases.(Schneps & Colmez, 2013)

9. Concluding Remarks

The field of forensic science has proven to be an indispensable asset to the law enforcement agencies and the criminal justice system for a significant period

exceeding one hundred years. The exponential progress in forensic technology has undeniably facilitated the resolution of an incalculable number of criminal cases.

The resolution of criminal cases serves to administer justice to both the afflicted victims and their respective families, while concurrently safeguarding the general populace through the apprehension and subsequent removal of individuals who perpetrate acts of violence within society. While the resolution of criminal activities undoubtedly constitutes an appealing objective for governmental entities, it is imperative to acknowledge that it should not be regarded as the ultimate and exclusive pursuit. To maintain the integrity of the criminal justice system, it is imperative that due diligence is exercised to guarantee the prosecution and conviction of individuals who are genuinely culpable, while simultaneously safeguarding the rights and liberties of those who are innocent. In the course of the past twenty years, it has become increasingly evident that the field of forensic science does not consistently ascertain the veritable culpability of individuals. There exists a multitude of rationales as to why the field of forensic science has been intricately associated with a significant number of erroneous convictions.

The principal factors contributing to the issue at hand encompass insufficient financial resources, deficient regulatory measures, and inadequate supervisory mechanisms. To safeguard the individuals of virtuous standing and effectively ascertain the culpable parties, it is imperative that forensic science receives appropriate financial support, meticulous regulation, and the establishment of competent bodies to effectively supervise the field of forensic science and probe into allegations of impropriety or dereliction of duty.

Ultimately, the paramount aim should be the cultivation of a scientific ethos within the realm of forensic science, with the intention of mitigating the probability of erroneously convicting individuals who are innocent. Simultaneously, it is imperative to ensure that this pursuit does not undermine the capacity of law

enforcement agencies and the prosecution to effectively ascertain, apprehend, and bring to justice those who are genuinely culpable.

The erroneous conviction of an individual who is demonstrably innocent represents a lamentable instance of justice being egregiously subverted. The identification of the shared factors associated with wrongful convictions has been accomplished by researchers and advocates who have conducted an in-depth analysis of exonerations. Within this body of research, it has been demonstrated that forensic science evidence is one of the contributing factors to these erroneous outcomes. In the context of erroneous convictions, it becomes crucial to delve into the intricacies and comprehensively comprehend the various processes through which forensic science exerts its influence, operating at both the microcosmic level of the individual case and the macrocosmic level of the broader system. Accordingly, extant psychological research has demonstrated that cognitive biases possess the capacity to engender fallaciousness within the realm of forensic decision-making, thereby potentially yielding erroneous results.

The demonstration of invalid forensic science testimony as an additional mechanism has been accomplished by legal scholars and scholars specializing in science and technology through their meticulous examination of trial records. Nevertheless, it is vital to acknowledge that these two mechanisms, namely cognitive biases and human decision-making, are not inherently separate entities. In fact, they often intertwine and exert influence on one another, as cognitive biases have the potential to impact all facets of human decision-making processes. In instances where wrongful convictions arise as a consequence of forensic misconduct, it becomes imperative to adopt a broader perspective and scrutinize the institutional and cultural dynamics that facilitated rather than impeded these results.(J. D.-J. Crim. L. & Criminology, 2010)

The available evidence suggests a potential decline in the contribution of forensic science to wrongful convictions, particularly in the context of DNA exonerations.

It is worth mentioning, nonetheless, that within the realm of both DNA and non-DNA exonerations, a significant proportion of 24% is attributed to instances where forensic science has been found to be erroneous or deceptive. Henceforth, it is very important to maintain a state of heightened awareness regarding the pivotal role played by forensic science in the occurrence of erroneous convictions. Simultaneously, endeavors to enhance the overall standards and efficacy of forensic practice should persist.(P. G.-Va. J. Soc. P. & L. 1996.)

DNA profiling and databases furnish law enforcement agencies with a highly efficacious instrumentality that has the potential to fundamentally transform the dispensation of justice on a global scale. Given the ongoing progress in DNA technology, it is plausible to assert that such databases may accrue enhanced value in the foreseeable future. Given the utilization of enhanced technological advancements in the examination of DNA samples, it is imperative to acknowledge that the acquisition of an extensive array of data pertaining to an individual becomes feasible. Consequently, it becomes paramount to recognize the indispensability of implementing heightened precautionary strategies in order to avert any potential malevolent exploitation of said information. The genetic profiles contained within the DNA databases necessitate utmost reverence and meticulous measures to safeguard the sanctity of human privacy.(Y. Y.-Am. J. Crim. L. 1994.)

In the majority of instances, the administration of justice necessitates a multifaceted equilibrium of numerous factors." For example, the appropriate utilization of DNA information while upholding the principles of privacy necessitates the intricate equilibrium to be achieved by the individuals and entities involved.(Y. Y.-Am. J. Crim. L. 1994.) The burgeoning utilization of DNA profiling, engendering infringements upon human rights and privacy, necessitates the implementation of specific measures to redress said infractions. Furthermore, it is crucial to implement strategies aimed at mitigating or diminishing the disparities that exist between developed and developing nations with respect to the incorporation of DNA technology within their respective systems of justice delivery. Henceforth, it is

necessary to direct and regulate the utilization of technological breakthroughs in order to yield advantages for the entirety of society. If studies pertaining to genetics and the forensic utilization of DNA data within the justice delivery system are not properly regulated, it is conceivable that prolonged disputes and detrimental conflicts between different jurisdictions may ensue. Henceforth, it is essential to acknowledge the potential significance of national and international initiatives in the realm of regulating abuse and facilitating the appropriate utilization of genetic samples and associated details within the justice delivery system.

Ultimately, one could suggest that there exist two diametrically opposed yet indispensable pursuits. One pertains to the fundamental entitlements of individuals and the preservation of their privacy, while the other concerns the enforcement of legal measures aimed at safeguarding public welfare and maintaining societal security. Hence, it is vital to implement suitable strategies to strike a harmonious equilibrium between the constitutional assurance of privacy rights and other fundamental human rights, while simultaneously fulfilling the government's obligation to safeguard public safety and promote the welfare of individuals within their jurisdiction. The central concept or principle revolves around the veneration and legal safeguarding of the community while simultaneously upholding the sanctity of personal privacy.(L. M.-Ark. L. Rev. 2009.)

Chapter VII

CONCLUSION AND SUGGESTIONS

1. Conclusion

The realm of criminal activity is a multifaceted domain. Crime manifests itself in various settings, encompassing places of employment, educational institutions, residential dwellings, commercial establishments, vehicular domains, public thoroughfares, and, notably, the cyberspace, which has witnessed a burgeoning prevalence in recent times. Criminal activities are perpetrated incessantly throughout the diurnal and nocturnal periods, spanning across diverse geographical locations within the nation, encompassing rural, suburban, and urban settings.

incidents of arson, gunshots, and unauthorized entry. Certain criminal activities possess the capacity to surpass geographical boundaries, thereby necessitating a transnational approach to law enforcement. Particularly, offences pertaining to homeland security demand the collection and analysis of forensic evidence to effectively address the associated challenges.

The government, courts, and media have increasingly directed their efforts towards the strength and efficacy of the present forensic science system. The burgeoning cases of exoneration facilitated by DNA testing has engendered heightened skepticism regarding the veracity of certain forensic science methodologies, thereby leading to a reevaluation of the reliability of these procedures. This reconsideration has also brought to light the disconcerting fact that individuals who are indeed culpable occasionally evade conviction and subsequently elude punishment

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The emergence of novel scientific advancements with potential applicability to forensic investigation has engendered apprehensions pertaining to the availability of resources, adequacy of training, and the capacity to effectively incorporate these innovative strategies. The current predicament of an overwhelming accumulation of unresolved cases, stemming from the inadequacy of resources and personnel within crime laboratories, elicits apprehension regarding the efficacy and effectiveness of the criminal justice apparatus. It is a well-established reality that numerous forensic tests, specifically those employed in the determination of toolmarks or bite marks, have not undergone rigorous scientific examination. The majority of these methods were formulated within the context of crime laboratories, with the primary objective of facilitating the examination of evidence derived from specific crime scenes. However, the comprehensive exploration of their constraints and underlying principles did not occupy a prominent position on the research agenda.

As previously indicated, a confluence of various factors has coalesced in recent decades, thereby imposing escalating pressures upon an already burdened, incongruous, and inadequately supported forensic science framework. Different variables have not only exerted pressure on the system's capacity but have also engendered significant inquiries and apprehensions regarding the veracity and dependability of certain forensic methodologies and approaches, as well as the way forensic evidence is presented to juries and courts.

The backlog is further contributed by an escalation in the number of expeditious laboratory result demands made by law enforcement agencies and prosecutors. Prosecutors are progressively placing greater reliance on the utilization of laboratories to furnish results prior to granting charges, and there has been a notable surge in requests for supplementary work towards the concluding stages of a case, specifically in the period immediately preceding the trial. The issue of backlogs is

exacerbated by the increasing number of demands for testing from police agencies. Consequently, forensic laboratories face the dilemma of effectively managing the analysis of both "older" and "cold" cases alongside new cases. To deploy resources efficiently, they must make strategic decisions regarding the prioritization of evidence to be analyzed.

The presence of backlogs in the criminal justice system can have significant ramifications. Firstly, innocent individuals who have been wrongly accused and are awaiting trial may experience prolonged periods of imprisonment. This not only infringes upon their fundamental rights, but also perpetuates an unjust system. Secondly, the delay in investigating individuals who have not yet been charged can impede the progress of justice. This delay hampers the ability to gather evidence, interview witnesses, and ultimately bring charges against potential offenders. Lastly, the existence of backlogs can inadvertently lead to the discharge of guilty suspects who, once freed, may go on to perpetrate additional crimes. This highlights the urgent need to address and rectify the issue of backlogs within the criminal justice system.

The potential emergence of challenges pertaining to expeditious adjudication may ensue when the temporal duration of testing is protracted due to the presence of backlogs. Furthermore, the presence of backlogs serves as a deterrent for law enforcement personnel and organizations, impeding their willingness to submit crucial pieces of evidence. To mitigate the accumulation of pending cases, laboratories may opt to impose limitations on the acceptance of evidentiary submissions.

In conclusion, it is imperative to acknowledge that mishandling or inappropriate analysis of evidence and laboratory tests, as well as the presence of scientific evidence that may convey a misleading sense of importance, can have profound implications. Furthermore, the potential for prejudice, inefficiency, or insufficient internal controls within the forensic scientists and their laboratories must not be

overlooked. Such circumstances have the capacity to misguide the jury or court, ultimately resulting in erroneous convictions or exonerations. If juries experience a decline in their trust in the dependability of forensic testimony, there exists the potential for valid evidence to be disregarded, consequently leading to the possibility of wrongful convictions of innocent people or the acquittal of guilty parties.

In the preceding two decades, notable progressions in select forensic science fields, specifically the utilization of DNA technology, have substantiated the considerable untapped ability of certain realms within forensic science to aid law enforcement in the identification of perpetrators. Numerous criminal cases that may have previously eluded resolution are presently being successfully resolved due to the invaluable contributions of forensic science, which aids in the identification of the culpable individuals.

These advancements, nevertheless, have also brought to light the fact that, in certain instances, substantial knowledge and testimonies derived from flawed forensic evaluations may have played a role in the erroneous punishment of individuals who are, in fact, innocent. This fact has effectively showcased the potential peril that arises from assigning excessive significance to evidence and testimony that stem from flawed examination and evaluation. Furthermore, the inclusion of unclear or overstated expert testimony has occasionally played a role in the acceptance of incorrect or deceptive evidence.

While it is true that the primary responsibility for criminal law enforcement lies with state and local jurisdictions, it is unfortunate that these bodies frequently face significant deficiencies in the essential resources required to establish and sustain robust forensic science laboratory systems. These resources encompass financial support, personnel, comprehensive training, and state-of-the-art equipment.

The issue of disintegration is further exacerbated due to the lack of standardization or consensus on functional guidelines and practices within and between

jurisdictions in various forensic science fields of study. The current situation regarding the licensing of forensic professionals and the authorization of crime laboratories lacks a sufficient level of coherence. Indeed, it is a widely acknowledged fact that most jurisdictions do not impose a requirement for forensic experts to possess a license. Furthermore, it is worth noting that the vast array of forensic science areas currently in existence lack obligatory certification programs.

Forensic testing facilities in India have a long history, dating back to the British colonial era. Today, these research institutes are organized into a three-tiered framework, consisting of Central, State, and Regional FSLs (CFSLs, SFSLs, RFSLs). Moreover, there are district mobile forensic units (MFSUs) that provide further support. At present, there are 117 operational FSLs, out of which 10 have received accreditation from the National Accreditation Board for Testing and Calibration Laboratories (NABL).

There is a total of eight CFSLs, with one of them being the CFSL Unit in Shimla. These CFSLs are under the governance of the Union Ministry of Home Affairs (MHA) through the Directorate of Forensic Science Services (DFSS). The CFSL in Delhi was previously under the jurisdiction of the Central Bureau of Investigation (CBI). Throughout the states, there are 31 SFSLs and 78 RFSLs that are currently operational and are overseen by the home or police departments of each state.

Although the DFSS does not have direct control over state and regional laboratories, it does offer monetary and technical assistance to all FSLs. In contrast to this framework, forensic medicine falls under the jurisdiction of the Ministry of Health and Family Welfare (MoHFW) and is overseen by the Directorate General of Health Services (DGHS). Autopsies and examinations in medico-legal cases (MLCs) are typically carried out in government-run healthcare facilities and medical colleges.

Despite the increasing attention given to forensics, there is a notable lack of empirical research on the difficulties and requirements of FSLs in India. Past

reports, such as the National Human Rights Commission's 'State of the Art of Forensic Science: For Better Criminal Justice' (1999), and the Ministry of Home Affairs reports 'Perspective Plan on Indian Forensics' (2010) and 'Report on Scientific Performance Audit of DFSS HQ and its CFSLs' (2011), have highlighted major issues pertaining to the lack of sufficient finances, employees, and infrastructural facilities in laboratories.

There are differences in the planning and execution of forensic science and forensic medical training. While forensic science is imparted as a branch of science, forensic medicine is offered as a discipline of medicine with a post-graduate specialization. Though, many forensic specialists in India are really graduates of pure scientific programs who went on to specialize in forensic science. As of right now, it is known that 48 Indian public and private educational facilities provide forensic science programs leading to undergraduate, graduate, and doctorate degrees as well as diplomas and other credentials.

Initially under the Bureau of Police Research & Development (BPR&D) and then directly under the MHA, the National Institute of Criminology and Forensic Science (NICFS) was founded in Delhi in 1972 to conduct research, provide instruction, and training in forensic science and criminology. The Lok Nayak Jayaprakash Narayan National Institute of Criminology and Forensic Science (LNJN NICFS) was the new name given to it in 2003.

In Gandhinagar, the Gujarat Forensic Science University (GFSU) was founded in 2008. The Parliament renamed GFSU and LNJN NICFS as the National Forensic Science University (NFSU) and designated it as a Centre of National Importance under the National Forensic Sciences University Act, 2020. (National Forensic Sciences University Act, 2020) Six other NFSU sites are currently operational, and there are plans to add more.

2. Suggestions

Forensic science professionals and evidentiary materials are regularly employed in the pursuit of justice within the realm of the criminal justice system. DNA examinations can be employed to ascertain the origin of sperm discovered on an aggrieved of sexual assault, thereby establishing potential culpability of the party incriminated. Similarly, the examination of a concealed fingerprint on a firearm can be utilized to ascertain whether the defendant had physical contact with said weapon. Furthermore, drug analysis can be employed to ascertain the legality of pills discovered in an individual's possession.

An autopsy can be conducted to ascertain the reasons and events surrounding the demise of a homicide victim. For proficient forensic science professionals to provide effective testimony regarding forensic evidence, it is imperative that they initially locate the evidence in a condition suitable for analysis and subsequently ensure its appropriate preservation. A latent fingerprint that exhibits significant smudging upon discovery renders it impracticable to effectively preserve, scrutinize, or elucidate.

Moreover, it is imperative to acknowledge that DNA tests conducted on a specimen that has been tainted or polluted in any manner are inherently unreliable in terms of accurately ascertaining the identity of an individual or exonerating them as the accused of a criminal act. These matters pertain to the crucial handling of forensic evidence. The primary quandary faced by the legal system in its substantial dependence on forensic evidence pertains to the inquiry of whether, and to what degree, scientific principles are present within a particular forensic science discipline.

Two fundamental inquiries should serve as the foundation for the legal acceptance and utilization of forensic evidence in criminal proceedings: The first aspect under consideration pertains to the degree to which a specific forensic discipline is grounded in a dependable scientific procedure that enables it to effectively examine evidence and communicate its findings with precision. The second aspect concerns

the degree to which professionals in a given forensic area depend on subjective human interpretation, which may be susceptible to errors, biases, or the lack of rigorous functional protocols and effective performance criteria.

Given that individuals facing criminal charges are ultimately indicted or acquitted based on the testimony provided by forensic science experts, the reliability of the evidence presented assumes paramount significance. Moreover, in conjunction with safeguarding individuals unjustly accused of crimes they did not perpetrate, the objective is to shield society from individuals who have engaged in unlawful activities. It is vital for law enforcement officials to possess a sense of assurance regarding the reliability of the methods employed in forensics.

The adversarial procedure as it pertains to the admission and rejection of scientific evidence, is not optimally aligned with the objective of ascertaining "scientific truth." The judicial system faces several challenges that impede its effectiveness. One such challenge is the limited scientific knowledge possessed by judges and lawyers, which hinders their ability to fully understand as well as evaluate forensic evidence in an informed manner. Additionally, trial judges, who often make evidentiary decisions in isolation, lack the support and input of their judicial peers, and are frequently constrained by time limitations that prevent thorough research and contemplation.

Developing Legislation that is Neutral towards Technology

It is crucial to approach the progression of computer-specific legislation in a way that guarantees consistency in its implementation and comprehension, regardless of the jurisdictional context. Simultaneously, it is crucial for legislation to be broad enough to accommodate advancements in technology, ensuring that it can be applied to future technologies. Additionally, it is essential to establish measures for safeguarding computer privacy.

Lawmakers should focus on creating technology-neutral legislation that specifically addresses important factors such as intent, while also allowing for a wide range of methodologies to be used. Furthermore, it is important for legislation to acknowledge the longstanding difficulties in analyzing digital evidence and offer reasons for the need to thoroughly examine computer materials. These challenges may include the large amount of data stored in computer systems, the presence of encrypted data, damaged media, and limited resources.

Implementing a System of Responsibility for Internet Users

It is essential to establish legislation that guarantees privacy for individuals who genuinely require it, while also preventing unrestricted concealment. This would enable individuals to browse the internet without revealing their identities, ensuring their privacy and security. It also provides a means for law enforcement to track down perpetrators, attackers, or terrorists who try to hide their illegal activities. We must ensure that our focus on the globalization of communications and information does not overshadow the importance of national security. Regrettably, achieving such a balance is quite challenging. Democratic principles necessitate heightened demands on privacy when conducting confidential activities, which can sometimes hinder law enforcement efforts. In addition, the principles of open markets and capitalist ideologies necessitate a means of communication that allows for global distribution, which was not possible before the advent of the World Wide Web. Therefore, creating legislation that promotes economic growth in line with the global market, while still allowing for individual opinion, is a challenging endeavor. Legislatures must also grapple with concerns regarding state sovereignty, ensuring that the government acts as a mediator rather than a dictator.

Enhancing Public Awareness and Strengthening Research Capabilities

Historically, crime associated with computers has not received a lot of focus from the majority of society, who fail to fully grasp the deceitful character of this phenomenon. Therefore, it is crucial to implement a widespread educational

initiative that targets various segments of society, such as politicians, instructors, law enforcement personnel, individual consumers, and youngsters.
It is vital to have a comprehensive understanding of computer crime, recognizing the inherent risks involved in such acts. It is important for everyone to be conscious of both the risk and the rapid expansion related to computer crime. Once established, this shared understanding should lead to more funding for computer-related initiatives and greater transparency and collaboration with the public. Furthermore, it is important to establish initial assessments of prevalence and classifications of perpetrators.
The imperative for the forensic science society lies in the establishment of robust governance mechanisms that facilitate the adoption and dissemination of an assertive and enduring strategic plan aimed at fortifying the field of forensic science. The strength and independence of governance are essential to effectively recognize the constraints of forensic science techniques. Furthermore, it is crucial for governance to establish powerful connections with the scientific research foundation of the nation, as this will facilitate substantial progress in the field of forensic science procedures.

The efficacy of the governance framework lies in its capacity to establish suitable incentives that encourage jurisdictions to embrace and uphold optimal practices, while concurrently implementing punitive measures to deter the adoption of unfavorable techniques. To bring about enhancements in the realm of forensic science training, it is imperative for the initiative to possess a substantial degree of influence among educators.

The system must possess the capability to discern and ascertain established norms or benchmarks, and subsequently exert authority in ensuring their adherence. The governance entity should possess a strategic orientation that aligns with and garners credibility within the law enforcement community. However, it is essential that this entity possesses capabilities and competencies that transcend the confines of this specific domain.

Forensic science plays a multifaceted role that extends beyond its application in law enforcement. Moreover, when employed within the realm of law enforcement, it is vital that forensic science be readily accessible to all relevant stakeholders, including law enforcement officers, prosecutors, and defendants within the criminal justice system. The establishment responsible for governing the forensic science community should not primarily be obligated to law enforcement.

The magnitude of possible disputes of interest arising from the divergent requirements of law enforcement and the wider domain of forensic science is considerable. The current state of affairs reveals a dearth of agencies possessing the requisite capacity and suitable mandate to assume the multifaceted duties and obligations essential for the effective governance and enhancement of the forensic science community. The assigned tasks necessitate the requirement of an unrestrained and objective approach, with a minimal presence of bias. What is required is the establishment of a novel, robust, and autonomous institution devoid of any historical affiliations, possessing the requisite power and resources to effectively execute a novel program aimed at resolving the myriad issues encountered.

The Requirement for Integrated Governance

The elucidation of the advantages that shall ensue from the establishment of a robust, autonomous, strategic, cohesive, and adequately financed federal initiative aimed at bolstering and supervising the various branches of forensic science within our nation is unequivocal: The objective of this initiative is to

1. enhance the nation's capacity in accurately discerning the actual culprits while eliminating any individuals who have been wrongly implicated.
2. It aims to strengthen the nation's capability in efficiently addressing, attributing, and legally pursuing threats to the security of the homeland.
3. it seeks to diminish the probability of convictions being based on erroneous data.

4. It is imperative to create a robust scientific framework for the various domains within the field of forensic science. This entails enhancing the quality of education and training programs, as well as implementing stringent licensing and accreditation processes. By doing so, the forensic science community will be well-positioned to harness the full potential of existing and forthcoming scientific breakthroughs.

Verification of Novel Approaches

One specific objective of scientific inquiry involves the verification of novel methodologies to ascertain their dependability across various circumstances and discern their inherent constraints. A rigorously constructed experiment, devoid of any inherent bias, is meticulously devised to yield valuable empirical evidence in support of or against a given hypothesis. The data which are obtained through systematic and established observations conducted under carefully defined and monitored circumstances, are subsequently subjected to analysis to provide evidence either in favor of or against the proposed hypothesis.

An essential component of the verification process entails the dissemination of these research inferences through publication in esteemed scholarly journals. This enables subject matter experts to thoroughly evaluate, scrutinize, and assess the reproducibility of the findings. It is imperative that these publications incorporate unambiguous articulations of the hypotheses being investigated, alongside comprehensive elucidation of the experimental procedures, the ensuing data, and the subsequent data evaluation, thereby facilitating the replication of said research.

Techniques that are provided with a higher level of specificity, such as DNA analysis, wherein specific genetic loci are to be contrasted, possess a higher degree of credibility and are also more conducive to systematic enhancement relative to approaches that strongly rely on the subjective judgements of the investigator. The temporal validation of outcomes engenders a heightened sense of assurance. Furthermore, the scientific culture fosters a perpetual inclination towards inquiry

and enhancement. Henceforth, it is imperative for the pertinent scientific community to diligently verify the enduring validity of set up findings amidst novel circumstances, while ensuring their resilience in light of emerging knowledge.

To ensure the reliability of DNA forensic analysis, it is imperative.

1. To establish and maintain forensic DNA testing research facilities. These specialized facilities play a crucial role in the accurate and objective examination of DNA evidence, thereby contributing to the integrity of forensic investigations.
2. By adhering to rigorous scientific protocols, employing state-of-the-art equipment, and implementing stringent quality control measures, these laboratories strive to uphold the highest standards of accuracy, precision, and reproducibility in DNA evaluation.
3. To ensure the integrity and reliability of DNA evaluation, it is vital for research facilities to establish and adhere to a comprehensive standard operating protocol for each method employed. This protocol should encompass various aspects, including the specification of reagents, the specimen preparation methods, extraction procedures, equipment requirements, and controls. By implementing such standardized procedures, laboratories can effectively streamline their DNA evaluation procedures and facilitate consistent and accurate analysis of data.
4. The laboratory is required to oversee the analytical method by implementing suitable controls and standards. These include quantitation standards, which serve to estimate the quantity of human nuclear DNA obtained through the extraction process.
5. The laboratory is required to conduct an annual assessment of its DNA processes, or whenever significant modifications are made to the protocol(s), by comparing them to a suitable International standard reference material.

6. The laboratory is necessitated to possess and adhere to written comprehensive regulations pertaining to the interpretation of data.
7. The laboratory is responsible for conducting verification procedures to ensure that all control results fall within the predetermined tolerance limits.

Error in Evaluation

Like other scientific inquiries, laboratory examinations performed by forensic experts are susceptible to measurement error. The error serves as a manifestation of the inherent merits and constraints associated with the specific scientific methodology employed. For instance, the techniques employed to quantify the concentration of ethanol in an individual's bloodstream or to determine the quantity of heroin present in each specimen are subject to inherent limitations, thereby yielding results that fall within a range of potential values. In conjunction with the built-in constraints of the measurement method, a multitude of additional variables may be present and have the potential to impact the precision and reliability of laboratory evaluations. Various variables that may contribute to the aforementioned issues encompass inadequacies in the reference materials employed during the analysis, potential errors arising from equipment malfunction, deviations from the validated range of environmental situations inadvertent mix-ups or pollution of samples, inadvertent errors in recording, and a plethora of other potential sources of error.

The Elimination of Bias

The human faculty of judgement is susceptible to a myriad of biases, owing to our innate tendency to absorb and integrate environmental indicators into our cognitive evaluations, albeit without explicit acknowledgment. The psychological evaluations in question may potentially be influenced by unfounded presumptions and an element of excessive self-assurance that remains unacknowledged by the individuals involved. These cognitive biases do not arise from inherent character

deficiencies; rather, they are prevalent attributes of the decision-making process and cannot be eradicated through sheer determination.

The various sources of bias discussed herein are widely recognized within the scientific community, and considerable scholarly endeavors have been undertaken to comprehend and alleviate their impact. The primary objective is to maximize the objectivity of scientific inquiries, thereby minimizing the influence of the investigator on the obtained outcomes. Several scientific disciplines, particularly the realm of biopharmaceutical studies pertaining to treatment protocols and drugs, have established methodologies aimed at mitigating the influence of biases. These methodologies include the implementation of double-blind tests and the employment of independent verification, both of which serve to minimize the potential effect of subjective inclinations.

Furthermore, the field of science endeavors to disseminate its discoveries, outcomes, and inferences through the process of publication, thereby subjecting them to rigorous scrutiny by independent peers. This practice facilitates the examination of potential biases inherent in the investigative methodology and allows for the replication of unforeseen outcomes. Mitigating, or counterbalancing, a predisposition is a paramount endeavor. Even disciplines with firmly set up methodologies to mitigate the impact of prejudice can still benefit from enhancement. The scholarly inquiry into the significant subject matter of cognitive bias within the realm of forensic science has regrettably been lacking in depth and breadth.

There exists a paucity of forensic science methodologies that have successfully devised sufficient metrics to assess the veracity of conclusions posited by practitioners within the field of forensic science. It is imperative that all findings pertaining to each forensic scientific technique duly account for the inherent ambiguity in the measurements undertaken. Consequently, comprehensive

investigations must be undertaken to facilitate the accurate estimation of said values.

The judiciary has already exhibited its competence in addressing a certain level of ambiguity in personalization, as evidenced by the effective utilization of DNA analysis despite its minimal, yet existent, margin of error.

The efficacy of forensic methodologies, leading to the categorization or personalization deductions, necessitates thorough assessment through meticulously executed and meticulously designed research endeavors.

The dearth of financial resources allocated to fundamental and practical research within the field of forensic science can be attributed to various factors. Forensic practice originated within the criminal justice and law enforcement systems, serving as its progenitor, and subsequently expanding therefrom. Numerous forensic science methodologies have been devised with the primary objective of facilitating the investigative phase of law enforcement endeavors.

Subsequently, these approaches have been modified to fulfil the secondary function of assisting in the prosecution process through the provision of courtroom testimonies. Hence, it is noteworthy that forensic professionals employed in public crime laboratories are frequently perceived as integral members of the prosecution team, rather than being recognized as integral contributors to the scientific enterprise. Furthermore, it is worth noting that certain domains within the field of forensic science place a greater emphasis on the learning model as a means of training, as opposed to formalizing their methodologies within a scientific structure.

It is imperative for the various branches of forensic science to establish meticulous protocols pertaining to the execution of subjective interpretations. Furthermore, these disciplines must actively engage in the pursuit of equally meticulous research and assessment initiatives. The advancement of research programs of this nature stands to gain substantial advantages by drawing upon the knowledge and insights

derived from various other domains. Particularly, the extensive corpus of research pertaining to the assessment of observer proficiency in the field of diagnostic medicine, as well as the discoveries made in cognitive psychology concerning the propensity for bias and fallibility in human observers, can greatly contribute to the progress of such endeavors.

When assessing the veracity of a forensic examination, it is imperative to elucidate the specific nature of the inquiry that necessitates the utilization of said examination. Hence, while certain methodologies may exhibit a degree of imprecision that precludes an exact discernment of an individual's unique identity, they nevertheless possess the capacity to furnish valuable and reliable insights pertaining to matters of categorization.

The establishment of standard terminology for reporting on and testifying about the outcomes of forensic science inquiries should be undertaken by the forensic advisory board. This initiative should be based on a comprehensive review of set up guidelines, including ISO 17025, and should involve collaboration with the institute's advisory board. In a similar vein, it is imperative to develop a standardized framework for the creation of exemplary laboratory reports across various forensic science fields. This framework should delineate the essential components that must be incorporated within these reports, thereby ensuring a comprehensive and cohesive presentation of data. To ensure compliance with accreditation and certification protocols, it is imperative that laboratories and forensic experts adhere to the utilization of standardized laboratory reports as a means of succinctly summarizing the outcomes of their examinations.

The imperative to undertake research endeavors arises from the necessity to effectively confront and resolve the multifaceted concerns pertaining to the precision, dependability, and soundness of the forensic science domains. The imperative lies with the central and state government to allocate financial resources

in a competitive manner towards the support of meticulously evaluated research endeavors within the subsequent domains:

1. Research endeavors aimed at developing the empirical foundations that substantiate the soundness and reliability of forensic methodologies.
   The focus of this inquiry pertains to the progression and institutionalization of quantifiable metrics used to assess the dependability and precision of forensic examinations.
2. The examination of the dependability and precision of forensic methods necessitates a comprehensive analysis that aligns with the practical application of said methods in real-life case scenarios. This analysis should be conducted by considering a representative specimen of forensic scientists and laboratories, thereby ensuring a balanced and unbiased representation of the field.
3. It is imperative for scholarly investigations to ascertain the boundaries within which analytic methodologies can reliably and accurately operate, taking into account the inherent variability of forensic evidence constraints.
4. The investigation pertaining to the determination of metrics for validity and precision necessitates a rigorous process of peer review and subsequent publication in esteemed scholarly journals. The focus of this inquiry lies in the advancement of quantifiable metrics that can effectively capture and assess the level of ambiguity inherent in the findings derived from forensic examinations.
5. Automated methodologies possessing the capacity to augment forensic innovations.

Furthermore, it is imperative to establish a strong correlation between investigations pertaining to the origins of human fallibility and endeavors aimed at quantifying and delineating the extent of such fallibility. It is recommended to undertake the formulation of standardized operating guidelines. These processes shall serve as the fundamental framework for the development of exemplary

protocols, with the primary objective of mitigating, to the utmost degree reasonably attainable, any potential biases and human-induced errors. The encompassing scope of these prescribed protocols necessitates their universal application to all forensic investigations that may be employed within the context of legal proceedings.

Enhancing Forensic Science Practice Oversight

Considering recent advancements, there has been a notable progression in the pursuit of measures to ensure quality within the realm of forensic science fields. However, the absence of standardized and obligatory protocols for standard reliability, coupled with prominent issues encountered by significant crime laboratories, has prompted increased scrutiny towards rectifying the inconsistent quality across laboratories. This necessitates the establishment of standards and implementation of best practices as a means to address this matter.

For the evaluation of expert testimony, the presence and adherence to standards that govern the implementation of the specific approach in question is extremely important. Standards and norms of excellence engender a milieu of professionalism, thereby enabling organizations and occupations to develop procedures, guidelines, and processes of commendable value, while concurrently upholding their autonomy vis-à-vis vested stakeholder groups.

Accreditation

Accreditation constitutes merely a solitary facet within an organization's comprehensive quality assurance program. This program ought to encompass additional components such as proficiency assessments, where applicable, as well as ongoing learning initiatives and other programs aimed at enhancing the organization's capacity to deliver superior services on a holistic level. In the context of laboratory facilities, the concept of accreditation does not imply infallibility on the part of accredited laboratories, nor does it suggest that a laboratory consistently employs optimal methodologies in all instances.

Rather, accreditation signifies that a laboratory conforms to a predetermined set of quality guidelines and operates within the confines of appropriate procedures as stipulated by these criteria. A laboratory that has obtained accreditation possesses a well-established governance structure that delineates the diverse procedures through which it conducts its operations on a regular schedule. This system also entails the continuous monitoring of said activities and the subsequent response to any variations to the prescribed acceptable procedures.

Such responses are executed in a systematic and deliberate manner, reflecting careful consideration. The necessity for external oversight in the engaging laboratory is imperative in order to prevent the development of standards that are biased towards self-interest and lacking in depth. Furthermore, this oversight serves to eliminate the possibility of resorting to expedient measures when confronted with competing needs that may compromise the integrity of quality control. Furthermore, it is worth noting that accreditation plays a pivotal role in fortifying the bonds within the professional community, facilitating the dissemination of exemplary methodologies, and affording laboratory personnel with firsthand exposure to the viewpoints and anticipations of esteemed leaders within the field.

Several essential components of accreditation programs that could potentially be integrated into a compulsory accreditation system for forensic science encompass the following aspects:

1. The establishment of a nationwide entity that can facilitate and oversee the accreditation procedure.
2. The implementation of an execution procedure that includes specific criteria determining the eligibility of organizations to employ for accreditation.
3. The inclusion of a self-evaluation mechanism, enabling organizations to assess their own performance and compliance with accreditation standards.

4. The incorporation of an external evaluation procedure, which involves on-site visits conducted by external evaluators to thoroughly assess the organization's adherence to accreditation requirements.
5. The provision of an appeals process, allowing associations to challenge accreditation decisions if they believe there are valid grounds for reconsideration.
6. The implementation of a recurring assessment and external review cycle, ensuring that organizations undergo periodic assessments to maintain accreditation status.
7. The establishment of a comprehensive set of standards that serve as the basis for evaluating organizations seeking accreditation.

Nevertheless, as time progresses, there is a potential for a decrease in the probability of infringements transpiring. Furthermore, instances of breaches ought to serve as a catalyst for heightened examination by an accrediting entity. Furthermore, the establishment of education as a prerequisite for accreditation serves as a mechanism through which gradual modifications and enhancements in quality can be attained on an individual basis.

In India the administration of Laboratory Accreditation operations falls under the purview of the Board for National Accreditation Board for Testing and Calibration Laboratories (NABL). This is accomplished through the active involvement of Technical Committees and Evaluation Panels, which serve as the suggesting bodies. The NABL system is founded upon the principles and guidelines outlined in the ISO/IEC 17011 standard, which pertains to the accreditation bodies. Additionally, it adheres to the ISO/IEC 17025:2005 standard, which delineates the fundamental standards for the expertise of laboratories for testing and calibration.

To streamline the operations of the National Accreditation Board for Testing and Calibration Laboratories (NABL), it is imperative for both the central and state government to grant authorization and allocate funds to NABL. This will enable

NABL to collaborate with government testing facilities, educational institutions, and private laboratories, while also seeking guidance from Scientific Working Groups.

The primary objective of this collaboration is to devise mechanisms for enhancing measurement techniques, validation processes, reliability assessments, information dissemination, and proficiency testing within the domain of forensic research. Furthermore, it is crucial to set up standardized rules pertaining to forensic investigations, methodologies, and practices. The establishment of standards should be undertaken with the aim of aligning them with the most exemplary practices observed in the field.

These standards, in turn, should fulfil the dual purpose of functioning as instruments of accreditation for laboratories while also serving as comprehensive guidelines for the learning, training, and certification of professionals operating within the respective domain. The compulsory implementation of laboratory accreditation and individual certification for forensic science professionals is imperative, with the aim of ensuring the highest standards of quality and competence within the field. Moreover, it is crucial that all forensic science professionals are afforded the opportunity to partake in a certification process, thereby further enhancing their professional standing and expertise. When considering the establishment of suitable criteria for accreditation and certification, it is imperative for the National Accreditation Board for testing and calibration Laboratories (NABL) to duly consider the incorporation of established and widely acknowledged international standards. This includes, but is not limited to, the utilization of standards released by the esteemed International Organization for Standardization (ISO).

It is imperative that all laboratories and facilities, regardless of their public or private nature, undergo the process of accreditation. Furthermore, it is crucial that forensic science experts, upon meeting the necessary criteria, obtain certification

within a timeframe determined by the National Accreditation Board for Testing and Calibration Laboratories (NABL). It is important for forensic laboratories to implement standardized protocols for ensuring quality and quality control measures in order to uphold the precision and reliability of investigations and the professional conduct of forensic experts.

The National Accreditation Board for Laboratories (NABL), in collaboration with its esteemed advisory board, ought to institute a comprehensive code of ethics at the national level, encompassing all domains within the realm of forensic science. Furthermore, it is essential that the NABL actively promote the integration of this national code into the professional code of ethics upheld by various specialized societies within the field.

Furthermore, it is crucial for the National Accreditation Board for Testing and Calibration Laboratories (NABL) to delve into the examination of potential avenues for ensuring compliance and adherence to ethical standards among forensic analysts who engage in severe transgressions. The implementation of such a code could be facilitated by means of a certification procedure targeting forensic experts.

Proper Training and Education in Forensic Science

To effectively fulfil their duties, it is essential for forensic analysts to possess a comprehensive comprehension of the fundamental tenets, practices, and contextual nuances inherent in the realm of science, encompassing the scientific method. The current paradigm of training ought to shift its focus from the traditional method of transmitting practices through apprenticeship-like approaches, towards a more advanced form of education that is rooted in scientifically validated rules. In conjunction with acquiring a specific technique, it is imperative for a novice individual to engage in an extensive period of training or workshop, wherein they acquire the ability to perceive and replicate the proficiencies of a seasoned examiner.

Furthermore, the junior individual ought to familiarize themselves with the aspects to be measured, the pertinent population statistics, the prejudices and errors that must be circumvented, as well as other factors that may compromise the reliability of the evidence. Additionally, they should acquire the abilities to compute the probability of an accurate finding, and to proficiently record and provide the evaluation. One of the essential proficiencies that must be imparted through forensic science learning and training is the acquisition of requisite knowledge and expertise to comprehend the intricacies associated with decision-making in situations characterized by ambiguity, while also comprehending the underlying probabilities and limitations involved.

To rectify the prevailing inadequacies, it is vital to commence by enhancing the quality of undergraduate and graduate programs, while concurrently expanding avenues for ongoing professional development. The establishment of legitimate operations within the forensic science fields necessitates a foundation rooted in developed scientific understanding, standards, and practices. These foundational elements are most effectively acquired through the pursuit of formal education and training, as well as the diligent execution of research endeavors.

Education and training within the realm of forensic science fields fulfil a minimum of three distinct objectives. Initially, it is crucial to acknowledge that educational programs play a pivotal role in equipping and cultivating the forthcoming cohort of forensic practitioners. In recent years, there has been a significant increase in the percentage of secondary and postsecondary students who have exhibited a keen interest in the field of forensic science fields. Considering this, higher education institutions have developed novel certificates and degree curricula aimed at equipping students with the necessary knowledge and skills to pursue professions in the field of forensic science. Within the field of forensic science, one can identify various categories of practitioners.

Among these are criminalists, who are prominently employed in crime laboratories and constitute a significant portion of the forensic science workforce. Typically, criminalists commence their professional journey armed with an undergraduate degree. Conversely, there exist other practitioners within the realm of forensic science, such as pathologists, odontologists, entomologists, toxicologists, and anthropologists. Another cohort of forensic examiners comprises crime scene investigators, who typically lack advanced academic qualifications, with a significant proportion holding no educational attainment beyond an associate degree level.

Furthermore, it is imperative for forensic science practitioners to engage in ongoing professional development and training. The exploration of scientific advancements in forensic science techniques and the pursuit of research within the various disciplines of forensic science have garnered significant attention from practitioners, who recognize the imperative need to remain apprised of these novel developments. Forensic science professionals, in addition to their primary qualifications, may find it necessary to undertake supplementary training to obtain certification or to enhance their skill set for the purpose of career advancement.

Furthermore, it is imperative to provide comprehensive education to individuals utilizing forensic science analyses, particularly those within the legal profession. Judicial practitioners, legal professionals, as well as aspiring legal scholars, stand to gain considerable advantages from cultivating a more profound comprehension of the scientific foundations that underpin the various disciplines within the realm of forensic science. Such an enhanced grasping would enable these individuals to discern how the fundamental scientific soundness of techniques employed in this field significantly influences the interpretation of resultant findings.

Educational Forensics in the Judicial System

The importance of the forensic science society lies in the imperative to impart knowledge to the recipients of their services, thereby necessitating an in-depth understanding of said services and the associated lexicon.

The beneficiaries of forensic science examinations encompass a diverse range of stakeholders, including but not limited to law enforcement personnel, forensic pathologists, legal professionals, the judiciary, members of the public, and policymakers. The present section is dedicated to the realm of education within the legal sphere, specifically targeting the esteemed members of the judiciary, legal practitioners, and the esteemed individuals comprising the jury.

In contemporary times, certain members of the judiciary have encountered difficulties in comprehending the progressively intricate nature of scientific evidence. Mass tort litigation frequently incorporates sophisticated studies in the fields of epidemiology and toxicology. Antitrust cases frequently involve the utilization of intricate econometric models. The crux of patent litigation frequently revolves around contentious matters pertaining to intricate engineering principles.

The failure to adequately contemplate and analyze such evidence in a deliberate and comprehensive manner poses a significant risk to the integrity and autonomy of the judiciary. The proliferation of DNA technology as a means of identification within the realm of forensic science has served as a catalyst for the advancement of judicial education programs.

The primary objective of this educational endeavor is to impart knowledge and enhance the understanding of criminal justice professionals and other specialists concerning the scientific aspects of DNA examination and the legal complexities surrounding its utilization within the judicial setting. This educational program can encompass a comprehensive range of topics, including but not limited to the

1. description of the biological properties of DNA,
2. the historical development of forensic DNA examination,

3. interpreting forensic DNA laboratory reports,
4. factors to consider in postconviction DNA testing requests,
5. details about forensic DNA databases,
6. challenges involved in showing DNA evidence in court,
7. insights into the admissibility issues related to the use of DNA evidence, and an extensive glossary with fundamental definitions pertaining to forensic DNA analysis.

Regrettably, the opportunity to adequately train the majority of lawyers and judges may have passed by the time they begin their careers. Training programs can be highly advantageous for responsible individuals in the legal field, providing them with the necessary knowledge and skills in a relatively short period of time. To enhance the knowledge and skills of lawyers and judges, it is crucial for law schools to improve the quality of forensic science courses included in their curricula. This will ensure a long-term solution to keep legal professionals well-informed and up to date.

The Role of Judges in Evaluating Scientific Evidence

Contrary to popular beliefs about the ineptness of judges and their tendency to make unpredictable decisions, extensive research has shown that judges consistently reach similar conclusions in simple as well as intricate scientific cases. Even when judges have limited and deficient comprehension of scientific and technical evidence, researchers have found that the judge's results are generally considered justified.

Furthermore, there is evidence indicating that judges' mistakes in understanding evidentiary details can sometimes be attributed to erroneous presentations and instructions from attorneys and judges, particularly when it comes to statistical evidence. Curiously, judges often show reluctance in fully embracing the statistical significance of DNA evidence, despite expert recommendations. It is not uncommon for judges to express worries regarding laboratory errors and the

specimen pollution, even in cases where the opposing counsel does not bring up all of these problems.

New Advancements in Legislative Framework

An essential element of the legislative framework that governs forensic science is the recent introduction of new laws, such as the DNA Technology (Use and Application) Regulation Bill, 2019 and the Criminal Procedure (Identification) Act, 2022 (CPIA).The DNA Bill enables the recognition of specific groups of individuals, such as criminals, suspects, individuals awaiting trial, missing persons, and unidentified dead individuals, by utilizing DNA examination and establishing DNA databanks.(Parliament Of India Rajya Sabha Department-Related Parliamentary Standing Committee On Science And Technology, Environment, Forests And Climate Change.)

The goal is to establish a system for accrediting laboratories that perform DNA testing. These testing facilities are also required to provide the DNA data they collect from casework with the databanks. The Bill was submitted to the Parliamentary Standing Committee on Science and Technology by the Rajya Sabha in October 2019. The committee's report, which included multiple modifications, was brought up before Parliament in February 2021.(Parliament Of India Rajya Sabha Department-Related Parliamentary Standing Committee On Science And Technology, Environment, Forests And Climate Change.)

The Committee has proposed several important alterations. These modifications involve reevaluating the necessity of a crime-scene index and a suspect or undertrials index, narrowing down the scope of DNA testing and laboratories by modifying the definition of DNA profile, guaranteeing the autonomy of the DNA regulatory board by selecting a chairperson, reassessing the requirement for a regional DNA data bank, and guaranteeing that a magistrate holds a hearing and provides a reasoned order before directing the obtaining of DNA.

The Criminal Procedure (Identification) Act, 2022 (CPIA) aims to gather forensic indicators or specimens from specific groups of individuals, including prisoners, imprisoned and convicts. It enables the handling, retention, conservation, distribution, and destruction of these specimens, with the goal of identifying and investigating criminal cases and preventing crimes. The Act grants broad authority to various law enforcement and correctional officers to gather these specimens.

It also permits states to appoint an agency responsible for collecting, preserving, storing, and exchanging them. Additionally, the NCRB is entrusted with the responsibility of establishing and managing a database of the resulting forensic records. The regulations to be enacted under the Act can provide further clarity on the function expected of FSLs in this process. During the enactment of this law, there were multiple worries raised about the wide spectrum of measurements covered by the CPIA, the overarching autonomy granted, privacy concerns related to gathering and databasing such measurements, and the scientific and regulatory factors.

Financial Strategy & Spending

CFSLs receive funding from the central government, while SFSLs, RFSLs, and MFSUs are financed by their respective state governments and specific grants-in-aid from the central government. Testing facilities also generate revenue through charges for forensic tests carried out by them. (MHA, Resolution No. 25020/61/13/FW/MHA, 2013) In addition to regular budgetary grants, the central and state governments also provide finances through specific programs.

These include the Nirbhaya Fund Scheme under the Ministry of Women and Child Development, (Status Of Nirbhaya Fund, 2021) the Modernization of Police Forces (MPF) Scheme, and the Creation of RFSLs and DMFUs scheme under the MHA. The procedure of sanctions and approvals for the budget and expenditure of any government body, including FSLs, can be quite intricate at both the central and state level. The process of budget approvals and disbursement of funds is distinct from

the approvals needed prior to any expenditure. The procedure for approving expenditures may vary depending on the sum of the expenditure and the states where the laboratories are situated. These are regulated by financial rules and regulations, such as the Union Government Financial Rules, 2017 (GFR). (General Financial Rules, 2017)

The MHA's Integrated Finance Division is primarily responsible for accepting proposals for budgets and expenditures. It then works in tandem with the Ministry of Finance to handle accounting, internal audits, and budgeting on behalf of the MHA. The MHA exercises direct administrative and fiscal authority over CFSLs and provides grants-in-aid to states for FSLs within its borders. Nevertheless, these central government grants are not assured on a yearly basis and can fluctuate from one year to another and from state to state.

Home departments or ministries oversee the management of SFSLs, RFSLs, and MFSUs within a state, either through their own personnel or through their police departments. Administratively and financially, RFSLs are supervised by SFSLs, which in turn have administrative and financial authority over MFSUs via RFSLs or directly. Therefore, the funds that SFSLs receive are distributed among the laboratories they oversee. The below stated measures can address the challenges and concerns pertaining to financial strategy and spending: -

1. It is important for DFSS to engage in dialogue with state governments in order to establish a clear separation between FSLs and police departments. This separation is crucial to guarantee the fairness and dependability of forensic results that are presented in courts. This will also ensure increased financial autonomy for FSLs, streamlined budgeting procedures, and enhanced fund utilization.
2. It is important to dedicate central grants specifically for the growth of SFSLs and RFSLs. The funds should be sub-allocated to guarantee that the funds are spent appropriately throughout various budget categories.

3. It is important to ensure that funds from both central and state sources are distributed to laboratories at the start of each year in an even way. It is important to reconsider the financial authority of FSL directors, particularly in RFSLs, to account for the regular expenses associated with handling casework.
4. Directors of RFSL should have the authority to act as Drawing and Disbursement Officers (DDOs) in accordance with financial regulations. Additionally, there is a need to enhance collaboration between RFSLs and SFSLs in terms of financial strategy.
5. It would be beneficial to have individuals with financial expertise in each FSL to enhance budget formulation and financial assessment. DFSS and its state counterparts ought to carry out needs evaluation polls to improve the financial strategy for FSLs.

Hiring, Learning, And Training

The procedure of approving a position involves a thorough financial assessment by the department in charge and the careful review of the necessary regulations and requirements. To obtain authorization for posts, CFSLs must go through a process involving various government departments, including the MHA, the Ministry of Finance, the Department of Personnel and Training (DoPT) and the Ministry of Law and Justice. Acceptance from the relevant government ministries or departments is typically required for SFSLs. In addition, each state may need authorization from other ministries or departments. The below stated measures can address the challenges and concerns pertaining to financial hiring, learning and training of experts: -

1. To streamline forensic employment, it would be beneficial for DFSS to arrange meetings with FSL directors, officials from state police and home departments, state public service commissions, and staff selection commissions. This would help identify any obstacles in the hiring

procedure. The development of a National Forensic Recruitment Strategy, in collaboration with NFSU and the proposed Forensic Council of India (FCOI), is essential. This strategy will establish uniform qualifications and recruitment processes for both scientific and non-scientific positions in a Forensic Science Laboratory (FSL). Additionally, it will suggest improvements to current hiring practices for the central and state governments to consider.

2. DFSS and the proposed Forensic Science Regulator (FSR) should consider updating their work standards to align with advances in science, caseload patterns, and the level of staffing within the FSLs. This should be accomplished by engaging in discussions with the suggested expert Scientific Working Groups (SWGs) for various divisions, FSL directors, and the relevant state police and home department officials.
3. To accurately gauge the requirements of the organization, DFSS and the FSLs should consistently evaluate the demand for scientific and nonscientific positions, taking into account local caseload trends.
4. To enhance their working environments, FSLs should focus on addressing potential risks in the workplace and offering advantageous perks to their employees, such as medical insurance, access to psychological support, improved compensation, chances to conduct research, and travel allowances. It is also important for them to ensure that their positions are comparable to similar roles in other government institutions. DFSS should work closely with state governments to enforce the Flexible Complementing Scheme (FCS) in SFSLs and RFSLs. This scheme enables promotions regardless of vacancies, providing a more flexible approach.
5. It is essential to set up the Forensic Council of India (FCOI) to efficiently oversee the professional application of forensic science. This can be achieved by implementing a system of registration and licensing for forensic analysts. Registration for this should be determined by the

qualifying tests administered by FCOI and NFSU. In order to regulate forensic science education, it is necessary for DFSS, and NFSU to conduct a survey of the current educational programs and establishments. It is necessary for NFSU to establish and enforce requirements for the curricula, methods of instruction, facilities and laboratory supplies needed for forensic science programs.

6. The suggested FSR, with assistance from NFSU, aims to establish consistent training programs for fresh scientific recruits across various divisions. These programs will include elements of both theory and practice to ensure that recruits are well-prepared before taking on any casework. The suggested partnership between the FCOI and NFSU aims to provide ongoing forensic education programs for current forensic staff, focusing on the latest scientific and legal advancements.

Management of Cases

Investigative agencies frequently send a significant number of exhibits to laboratories that have no forensic value. This, in turn, leads to delays in resolving cases. To handle the increasing backlog and meet strict deadlines for investigations, certain forensic science laboratories (FSLs) organize special efforts to reduce the number of pending cases. This involves working extra hours to complete the necessary casework. However, this raises significant concerns about the accuracy of forensic examination.

It is common for laboratories to lack dedicated case-receiving divisions, which can lead to issues with the integrity of the case exhibits and the presence of insignificant details within case documents. Additionally, laboratories need record-keeping systems to ensure the proper maintenance of the specimen custody within the FSL. This is particularly important given the high number of pending cases and the extensive workload. Due to a shortage of qualified scientific personnel, laboratories

often neglect to perform a thorough technical assessment of the casework prior to offering their findings.

The below stated measures can address the challenges and concerns pertaining to management of cases:

1. It is important for DFSS to establish standardized guidelines for receiving cases. It is important to have competent workers in the case-receiving segments who are familiar with guidelines, context management procedures, and assessing the chain of custody.
2. Additionally, it is crucial that all cases go through a thorough technical and administrative evaluation to maintain the excellent standard of forensic investigation. An essential aspect of conducting a technical audit is thoroughly assessing the data and supplies used in the process of scrutiny to verify the accuracy of the findings presented.
3. An effective and streamlined case management approach should be implemented in all FSLs to guarantee effective handling of casework. It is essential for every FSL to have employees who are well-versed in data input and assessment. This will enable them to continually track and calculate caseload developments in each section, leading to improved internal oversight.
4. DFSS should develop rules that adhere to best practices for collecting and managing various types of forensic proof. It is crucial for NFSU to prioritize the development of training programs for police officers in crime scene management. Additionally, it is essential to ensure that FSLs are properly staffed to effectively deliver this training.
5. It is essential to ensure that the police have the appropriate supplies for evidence gathering. It is important to establish regulations and standards for the practice of forensic medicine, particularly regarding medical evaluations of individuals and autopsy tests.

6. In addition, it is crucial for medical professionals and staff to receive proper training to safeguard the integrity of biological specimens.

Development and Maintenance of Infrastructure

Setting up a laboratory necessitates a comprehensive grasp of the procedures employed in each forensic department and their requirements when analyzing various types of cases. The planning required for establishing an FSL should encompass various aspects such as maintaining standards of safety and health, preventing pollution, restricting entry to examination sectors to authorized scientific personnel only, designating distinct areas for scientific and non-scientific activities, and evaluating future division requirements. The need for more facility space and supplies for functional divisions is crucial for the FSLs. It directly impacts their current operational capacity and future efficiency. The below suggested measures can address the challenges and concerns pertaining to development and maintenance of infrastructure:

1. DFSS should collaborate with NFSU to carry out a comprehensive needs evaluation survey. This survey will help gain insights into the infrastructure-based requirements of FSLs. It is crucial to involve specialists from various fields such as forensic science, health and safety, architecture, civil engineering, and security to ensure a well-rounded understanding of the wants. This should be focused on creating a national plan for meeting these requirements. DFSS should work with states to ensure that sufficient funds are allocated for these objectives.
2. It is important to establish minimum standards for organizing and building of state laboratories, such as measures for pollution control, well-being and protection, waste elimination, and workflow management.
3. The DFSS should track and frequently inspect the state testing facilities to make sure compliance with these standards, particularly in terms of health and safety protocols, and deal with any execution difficulties.

4. To support the infrastructure growth of state laboratories, a central grant specifically designated for this purpose ought to be constantly provided, considering the significant capital investment required for equipment purchases. DFSS should aim to standardize machinery across FSLs to streamline purchasing procedures and minimize delays caused by monetary approvals.

Efficient Quality Control

Ensuring the precision and dependability of investigations counted on by courts is of utmost importance in the field of forensic science. This is achieved through quality supervision, which involves implementing quality control and quality assurance procedures. Effective management structures are crucial in identifying and reducing inaccuracies, particularly considering the significant impact they can have within the criminal justice system. In the field of forensic science, the qualities that are considered important include the expertise of the organization and its members, as well as the reliability of the testing techniques. This is done to guarantee the precision and dependability of the forensic investigations that law enforcement and courts rely on to settle civil and criminal litigation. The below suggested measures can address the challenges and concerns pertaining to efficient quality control:

1. DFSS and NFSU should arrange meetings with FSL directors and senior scientific personnel to establish an agreement on the significance and elements of quality management systems. These discussions will assist in identifying and providing specific solutions for the challenges that each FSL encounters in meeting quality standards.
2. It is recommended that DFSS develops a well-structured Action Plan with customized time frames for all FSLs to smoothly transition towards the adoption of quality management practices. DFSS should provide adequate

funds, supplies, training, and support to FSLs to ensure their successful completion of each phase.

3. It is important for FSLs to follow the guidelines of DFSS to create their own Working Procedure Manuals (WPMs) within a specified timeframe. Internal evaluations should be conducted to support their work. To provide guidance on drafting Working Procedure Manuals (WPMs), it is important to extensively circulate the WPMs that have been created by the groups of experts formed by DFSS among FSLs. It is important for laboratories to consistently review and update their WPMs to reflect any changes in laboratory setups or developments in technology.
4. To formalize quality management, it is important to provide support to FSLs. Further assistance and discussions with accredited laboratories, as well as NABL assessors, will be instrumental in this process. As many experts in the field have acknowledged, it is important to eventually establish compulsory accreditation for forensic laboratories. This should be done with flexible timelines that take into consideration the current challenges faced by the forensic system.

Legislation Governing Specialized Evidence by Experts.

The law places great importance on the reliability and precision of scientific results to make informed decisions. Thus, it is crucial for forensic science to be practiced with validity and reliability. Legislations should carefully evaluate the empirical foundation, constraints, and possible error rates of each forensic discipline before drawing any inferences. Considering the constant updates in scientific knowledge and the ongoing evaluation of the basis of various academic fields, it is crucial for the law to remain flexible and not restrict itself to past legal decisions when deciding on the admissibility and significance of forensic evidence. Developing an operational comprehension of the various forensic disciplines is necessary for judges and lawyers.

Section 45 of the Indian Evidence Act 1872 (Indian Evidence Act 1872 , s. 45) permits the use of opinions from specialists in various specialized fields, such as forensic science. In accordance to the judgement pronounced in *State of Himachal Pradesh v. Jai Lal* (Criminal Appeal No. 530 of 1997, SC 1999), it is necessary for an individual to possess specific skills, credentials, and professional expertise in a particular field to be considered a specialist. In the context of forensic science, this refers to a high level of proficiency in a specific forensic discipline, as well as a deep understanding of the technique or method of examination used in a case. It is essential to thoroughly evaluate the proficiency of forensic experts, especially considering the challenges associated with forensic science education, training, hiring requirements, and employee transfer between divisions.

Additionally, as per the Judgement (State of Himachal Pradesh v. Jai Lal (Criminal Appeal No. 530 of 1997, SC 1999), it is essential for experts to provide evidence to courts to ensure that their testimony is clear, persuasive, and thoroughly examined. The rulings under Section 45 of the Indian Evidence Act 1872 highlight the significance of expert scientific views that are clear, logical, and trustworthy. These opinions are crucial for allowing independent confirmation of the findings made. However, they fail to establish an unambiguous structure for defining what qualifies as 'science' and how to properly evaluate expert evidence. Consequently, judges have the responsibility of determining the admissibility of such evidence based on its relevance. However, this process can sometimes be subjective and lack guidance, potentially resulting in decisions that do not align with current scientific research in the forensic discipline. Thus, it is imperative for the Supreme Court to establish practice guidelines for trial courts regarding the assessment of the soundness and accurate implementation of scientific approaches.

Judicial decisions regularly emphasize the importance of providing the necessary 'data and materials' to enable judges to conduct a fair examination of expert opinions. Unfortunately, the absence of clear legal requirements has created confusion regarding the required documentation to be offered with the forensic

report in different forensic disciplines. This results in differences in reporting practices among FSLs and courts, which affects the ability of the defense to effectively question forensic evidence. Therefore, it is essential for the Supreme Court to clearly outline the necessary information that must be included in the forensic report.

In the Indian Evidence Act 1872 (now the Bharatiya Sakshya Adhiniyan 2023), the process for assessing the admissibility and significance of evidence lacks clear definition. Given that judges make their determinations following both parties have presented their evidence, it is possible for them to be influenced by confirmation bias as fact-finders. To avoid this, it is crucial for the Supreme Court to establish a clear stage for determining the admissibility of expert forensic evidence. Section 293 of the Code of Criminal Procedure 1963 (now section 329 of the Bharatiya Nagarik Suraksha Sanhita, 2023) states that a special provision has been made to excuse certain government scientific experts from being called to testify in court. To ensure the preciseness and dependability of the findings supplied, it is important to thoroughly cross-examine every expert, regardless of their professional designation. This is a practical aspect that should not be overlooked, even though it may require additional time away from casework. The section poses a significant challenge when assessing the credibility of forensic evidence, and the validity of it should be reevaluated due to its possible effect on the right to a fair trial, as ensured by Article 21 of the Constitution.

The deficiencies in the legal structure for evaluating expert forensic evidence are highlighted by the way the court handles DNA evidence. It is reassuring to note that courts have constantly highlighted the importance of ensuring the correct gathering, wrapping, dealing with, and transportation of biological specimens, as well as maintaining the chain of custody. Nevertheless, the courts also stressed the importance of maintaining a high level of quality control and confidence. However, they have not provided any specific details about these standards or the potential repercussions for not adhering to them. Due to the absence of clarity regarding the

required 'data and materials' for DNA testing, different courts have varying approaches to evaluating DNA evidence. This inconsistency is a challenge that needs to be addressed. In contrast to foreign courts, Indian courts do not consider statistical evaluation necessary for the admissibility of DNA reports. This is the main reason why testing facilities fail to carry out this sort of examination or include its results in their reports, even though it is an essential part of the DNA profiling technique. Judicial scrutiny should be applied by courts to ensure that scientific standards are upheld within DNA divisions, thereby enhancing the scientific application.

Directorate of Forensic Science Services (DFSS): DFSS has an extensive

responsibility to supervise the forensic science system in India. This includes encouraging innovation and research, creating plans for capacity-building, and ensuring quality management by establishing scientific standards and consistent rules for forensic practice, which should be widely shared. (Directorate of Forensic Science Services, n.d.) DFSS should be mushroomed and adequately staffed to include an Administration wing that can provide support to FSLs in areas such as budget oversight, infrastructure development, and quality control. Additionally, a Human Resources wing should be established to handle hiring, instruction, and employee welfare. It is important for DFSS to establish a structure for conducting regular needs evaluation surveys of FSLs in India. This will help direct actions and update legislation on forensics in a more effective manner. In addition, laboratory-wise yearly data on case intake, inspection, and pendency across divisions should be made accessible to the public.

State DFSS: To promote fairness and openness in forensic work and streamline

administration, SFSLs and RFSLs should be managed separately from the police department. This can be achieved by establishing a state DFSS, like the central DFSS, which would be led by a senior scientific officer. This would streamline administrative processes, enhance funding and expertise, and strengthen

collaboration between central and state authorities. The state DFSS would oversee adherence to the regulations, norms, and protocols established by the central DFSS.

The newly formed NFSU has a broad scope of responsibilities outlined in its parent Act. (National Forensic Sciences University Act, 2020) These include enhancing educational and training programs in the field of forensic science, providing support to governments in policymaking, creating forensic databases, and setting standards for forensic work. It should take on more responsibilities, such as assessing the requirements of FSLs, recruiting, and developing standards.

Proposal for the Regulation of Forensic Science

Although DFSS has a broad mandate, it lacks immediate oversight over SFSLs or RFSLs, which are responsible for most forensic investigations in India. Without the necessary legislative authority, it is unable to ensure adherence to scientific or quality standards.

Thus, it is crucial to develop a Forensic Science Regulation Act (FSR Act) that will create a regulatory framework for professionals, laboratories, and educational institutions in the field of forensic science. This act should be prepared and presented to Parliament for consideration. According to this Act, it is necessary to establish a Forensic Science Regulator (FSR) like the UK FSR.(Codes of Practice and Conduct Codes of Practice and Conduct for Forensic Science Providers and Practitioners in the Criminal Justice System, 2016) The FSR's role will be to create a code of conduct for Forensic Science Laboratories (FSLs) and ensure that they adhere to it. An establishment like the Forensic Council of India (FCOI) is crucial for overseeing the field of forensic science, both in terms of higher learning and professional practice. Its main objective is to guarantee that only skilled and competent individuals are responsible for conducting forensic tests.

Forensic Science Regulator (FSR): It is important to establish the FSR at both the

central and state level, with a team of knowledgeable researchers, forensic examiners, and representatives from various stakeholder groups. The organization will establish a set of guidelines for government and private FSLs and forensic examiners. It will ensure that these guidelines are followed, investigate any instances of violations, and limit the amount of casework in the FSL until the issue is resolved. It will also offer technical assistance to FSLs and create discipline-specific Scientific Working Groups (SWGs) to create best practices and scientific standards to assist FSLs in establishing their own protocols and Working Procedure Manuals (WPMs). The FSR will ensure that its rules are followed by conducting regular scientific inspections of FSLs. This will help provide the necessary technical assistance and allow for targeted resource strategies.

Forensic Science Councils of India (FCOI): An establishment FCOI identical to

the Bar Council of India (BCI) and the National Medical Commission (NMC) should be considered for the forensic science discipline. This would involve the inclusion of forensic specialists, heads of NFSU, DFSS, state DFSS, the suggested FSR, retired judges, and prominent lawyers. It will establish guidelines for forensic learning in India in collaboration with NFSU and assess and certify forensic programs and institutions according to these guidelines. Therefore, any new courses and organizations would need to obtain approval from FCOI and meet the prerequisites for curricula and infrastructure that promote experiential learning.

FCOI will also work together with NFSU to administer tests for licensing and certifying forensic scientists in various fields. Successful candidates will then be hired to FSLs. A record of authorized forensic analysts will be retained by FCOI at both the central and state levels. In addition, FCOI will set guidelines for professional behavior and ethics that forensic examiners must adhere to. They will also oversee and investigate any instances of infractions, and if necessary, revoke licenses in accordance with proper procedures.

The methodology employed in scientific inquiry is inherently unique and serves as a valuable complement to alternative approaches employed by individuals in their pursuit of knowledge and innovation. The methodologies employed within the realm of scientific inquiry possess an extensive chronicle of efficaciously constructing knowledge that is both utilitarian and reliable. Furthermore, these methodologies have proven instrumental in bridging lacunae within our understanding, whilst simultaneously rectifying previous fallacies. The scientific community highly values accuracy, objectivity, logical reasoning, meticulous observation and experimentation, reproducibility, effective management of ambiguity, and rigorous peer evaluation. These principles collectively facilitate the dependable accumulation, quantification, and analysis of evidence, ultimately leading to the generation of knowledge.

Ensuring the preciseness and dependability of forensic science practiced within FSLs is crucial in our pursuit of equitable and impartial examinations and criminal proceedings. The development of forensic services is a step in the right direction, but we must prioritize the quality of the methodologies being utilized. To accomplish this, it is essential to have a capable and authoritative Forensic Science Regulator (FSR) with a clear legal responsibility. The regulator should oversee and aid laboratory operations at both the state and central levels. By establishing autonomous Scientific Working Groups, the FSR aims to develop scientific guidelines and efficient procedures for all forensic divisions across FSLs. To guarantee fairness and financial autonomy, it is crucial to establish distinct administration for SFSLs and RFSLs in the states they operate in, autonomous from the police departments.

It is crucial for courts to maintain a dedication to excellence by establishing precise legal criteria for evaluating expert scientific evidence. Without a thorough evaluation of the accuracy of forensic approaches or how they are used by examiners, the management of forensic laboratories will lack scientific legitimacy. To facilitate a thorough examination of forensic evidence, it is essential to provide

comprehensive training to judges, prosecutors, and lawyers regarding the scientific foundations of various forensic disciplines and the innate constraints they possess. These advancements in the scientific and legal field will enhance the effectiveness and dependability of results in criminal investigations, benefiting both aggrieved and alleged individuals.

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