

FROM DUST TO DNA: FORENSIC INNOVATION AND THE RESOLUTION OF COLD CASES WITH SPECIFIC REFERENCE TO THE LONG ISLAND SERIAL MURDERS

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“Every contact leaves a trace. Over time, our ability to detect and interpret these traces has advanced immeasurably, transforming forensic science into an increasingly powerful instrument for revealing the truth and serving justice.”

- Adapted from Locard’s Principle

INTRODUCTION

“From the rudimentary fingerprints of yesterday to the sophisticated DNA profiles of today, forensic science has journeyed through decades of innovation, transforming the pursuit of truth from a shadowy endeavour into a beacon of light illuminating the path to justice.” This quote by Dr. Edmond Locard, a pioneer in forensic science, encapsulates the remarkable evolution of a discipline that lies at the crucial intersection of science and law. Forensic science, in its essence, is the application of a vast array of scientific disciplines – including biology, chemistry, physics, and computer science – to analyse physical evidence and provide objective information relevant to legal investigations.¹ The very roots of forensic application can be traced back centuries. For instance, the autopsy performed on Julius Caesar in 44 BC, while not “forensic” in nature as we know it today, represents one of the earliest documented instances of a medical examination used to determine the cause of death in a significant legal and historical context.² Over the subsequent centuries, the field gradually evolved through observations and rudimentary techniques. The development of fingerprint analysis in the late 19th century marked a significant leap forward, providing a unique and reliable method for individual identification.³ The 20th century witnessed an explosion of forensic advancements, from blood

typing and trace evidence analysis to the revolutionary impact of DNA technology in the late 20th and early 21st centuries.⁴ This continuous evolution has equipped investigators with increasingly powerful tools to uncover the truth, solve crimes, and ultimately contribute to a more just legal system.⁵ Forensic science, at its core, is the application of scientific principles and techniques to matters of criminal and civil law. Its journey from early observations to a highly specialised field has dramatically altered the landscape of crime investigation and justice delivery.⁶ Consider, for instance, the stark contrast between the era of Jack the Ripper in the late 19th century and modern times. During the Ripper’s reign of terror, investigators relied heavily on rudimentary crime scene observations and witness testimonies, with limited scientific tools at their disposal. The lack of advanced forensic techniques meant that the perpetrator remained unidentified, a chilling testament to the investigative limitations of the time. Fast forward to today, and we see countless cases solved with remarkable speed and accuracy thanks to advancements in DNA analysis, digital forensics, and trace evidence examination.⁷ The Golden State Killer case, where decades-old cold cases were cracked using genetic genealogy, stands as a powerful example of how far forensic science has come. Similarly, the rapid identification of

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² Xavier Chango et al. “Technology in forensic sciences: Innovation and Precision.” [2024] 12(8) Technologies 120

³ Donata Favretto, Jennifer P. Pascali and Franco Tagliaro, “New challenges and innovation in forensic toxicology: focus on the “New Psychoactive Substances” [2023] 1287 Journal of chromatography A 84,95

⁴ Viktor M. Shevchuk, “Methodological problems of the conceptual framework development for innovation studies in forensic science” [2020] 27(2) Journal of the National Academy of Legal Sciences of Ukraine 170, 183

⁵ Arian C van Asten, “On the added value of forensic science and Grand Innovation Challenges for the Forensic Community” [2014] 54(2) Science & Justice 170, 179

⁶ Simona Francese and Roberto SP King, *Driving Forensic Innovation in the 21st Century* (1st end, Springer 2024)

⁷ Robin Williams, “Shaping forensic science innovation” [2010] 50(1) Science & Justice 4, 7

⁷ Julie Mennell, “Fostering Forensic Innovation” [2010] 43(8) Measurement and Control 248, 250

suspects in contemporary crimes through real-time analysis of digital footprints and surveillance footage underscores this transformative progress.⁸

However, despite these remarkable advancements, the annals of crime history are replete with “cold cases” – investigations that remain unsolved, often for years or even decades after the initial crime.⁹ These cases present unique and formidable challenges. Evidence may degrade over time, witnesses may become unavailable or their memories fade, and the initial investigative leads may have been exhausted. The passage of time can obscure the truth, leaving victims and their families in a state of agonizing uncertainty. Yet, the evolution of forensic science offers a renewed hope for even the coldest of cases. The development of sophisticated technologies has breathed new life into investigations once deemed unsolvable.¹⁰ The case of the BTK (Bind, Torture, Kill) Killer, who terrorized Wichita, Kansas, for over three decades, serves as a compelling illustration. Despite years of evading capture, Dennis Rader was ultimately apprehended in 2005 through a combination of digital forensics – specifically, the tracking of metadata on a floppy disk he sent to the authorities – and traditional forensic analysis of his DNA. This case, along with numerous others, highlights the potent ability of modern forensic techniques to unravel mysteries that once seemed impenetrable.¹¹

This research paper endeavours to illuminate the pivotal role of the evolving landscape of forensic science in the resolution of cold case investigations, with a particular focus on the decades-long Long Island Serial Killer (LISK) case. Its primary objective is to showcase how advancements in forensic technologies, coupled with innovative investigative approaches, have

⁸ Nina Amelung and Helena Machado, “Governing Expectations of Forensic Innovations in Society: The Case of FDP” [2021] 40(4) *New Genetics and Society* 498, 519

⁹ Eric Martin, Dawn Elizabeth Schwarting, and Ruby J. Chase, “Serial killer connections through cold cases” [2020] *National Institute of Justice Journal* June 15, 18

¹⁰ Eli Siems, Katherine J. Strandburg and Nicholas Vincent, “Trade secrecy and innovation in forensic technology” [2022] 73 *Hastings LJ* 773, 778

¹¹ Ruth M. Morgan, “Forensic Science Innovation in the UK: Roadblocks and Enablers: Driving Forensic Innovation in the 21st Century: Crossing the Valley of Death” [2024] Cham: Springer International Publishing, 73, 88

¹² Lisnoff Howard, ‘Misogynists and Serial Killers’ (*CounterPunch*, 26 July 2023)
<<https://www.counterpunch.org/2023/07/26/misogynists-and-serial-killers/>> accessed 24 April 2024

provided new avenues for revisiting and ultimately making progress in this complex and enduring mystery. Employing a doctrinal methodology, this paper will analyse existing literature, legal frameworks, scientific advancements, and publicly available information surrounding the LISK investigation to understand the application and impact of forensic evolution in this specific context. By examining the developments and reported forensic evidence in the LISK case, this paper aims to underscore the potential of modern forensic science to bring answers and contribute to justice in even the most challenging cold cases.

HISTORICAL BACKGROUND

The Long Island Serial Killer (LISK) case stands as a stark and unsettling example of a cold case that haunted law enforcement and the public for over a decade.¹² The grim discovery began in December 2010, with the remains of several women found along Ocean Parkway in Suffolk County, Long Island, New York. As the investigation unfolded, more victims were discovered, totalling at least eleven individuals, primarily female sex workers who had advertised on Craigslist.¹³ The victims had been murdered and their bodies disposed of in a similar manner, suggesting the work of a serial killer.¹⁴ The case quickly garnered national attention due to its gruesome nature, the duration over which the murders appeared to have occurred, and the initial lack of significant breakthroughs.¹⁵ For many years, the LISK investigation remained a frustratingly cold case, embodying the challenges inherent in solving crimes where time erodes evidence and leads grow stagnant.¹⁶

To understand why a case like LISK could remain unsolved for so long, it’s crucial to consider the historical trajectory of forensic

¹³ Topacio A Sanchez, *Criminal Minds: The Modern Practices of Profiling* (2023)

<<https://poetcommons.whittier.edu/cgi/viewcontent.cgi?article=1038&context=scholars>> accessed 24 April 2024

¹⁴ Enzo Yaksic, ‘To Know and Cage the Devil: Policing Serial Murder in the Attention Age’ (Atypical Homicide Research Group Boston Massachusetts 02130 Research Gate, January 2024) <https://www.researchgate.net/publication/377078995_To_Know_and_Cage_the_Devil_Policing_Serial_Murder_in_the_Attention_Age> accessed 24 April 2024

¹⁵ Corey Kilgannon, ‘Potential Witnesses in Gilgo Beach Murder Case: Jailed Women’ *The New York Times* (New York, 1 October 2023) A1

¹⁶ Corey Kilgannon, ‘Wife of Gilgo Beach Suspect Gets a Documentary Deal.’ *The New York Times* (Digital Edition) (10 December 2023) NA

science.¹⁷ The late 19th and early 20th centuries witnessed the nascent stages of modern forensic techniques. The development of **fingerprinting**, pioneered by figures like Sir Francis Galton and Sir Edward Henry, provided the first widely accepted method of unique individual identification.¹⁸ This was a monumental advancement, allowing investigators to link individuals directly to crime scenes through latent prints. Similarly, early forms of **blood analysis** emerged, enabling the classification of blood types, though definitive individualization through blood would not come until much later with DNA typing. **Trace evidence analysis**, involving the examination of hairs, fibers, and other microscopic materials, also began to develop, relying heavily on microscopy and basic chemical tests. These early techniques, while groundbreaking for their time, had significant limitations in sensitivity and discriminatory power compared to modern methods.¹⁹

The limitations of these early forensic tools often played a significant role in cases going cold. Without the ability to definitively link suspects to crime scenes through unique biological markers like DNA, investigations relied heavily on eyewitness testimony, circumstantial evidence, and laborious manual comparisons.²⁰ Evidence could be easily overlooked, degraded, or contaminated without the rigorous protocols and sophisticated analytical techniques we have today. Furthermore, the understanding of crime scene preservation and the importance of meticulous documentation were still evolving.²¹ Cases lacking clear physical evidence or where initial leads went nowhere often stalled, eventually becoming cold.

When the LISK investigation began in 2010, forensic science had advanced considerably from its early stages.²² **DNA analysis**, particularly Short Tandem Repeat (STR) profiling, was a well-established and powerful tool for individual identification from biological samples like blood, semen, and hair roots.²³ **Mitochondrial DNA (mtDNA) analysis**, which examines DNA inherited

¹⁷ Michelle Kaminsky, *Serial Killer Trivia: Cold Cases: Fascinating Facts and Chilling Details from the Creepiest Unsolved Murders Ever* (Simon and Schuster, 2021)

¹⁸ Robin Williams, "Shaping forensic science innovation" [2010] 50(1) *Science & Justice* 4, 7

¹⁹ Elizabeth A Gardner, Rana DellaRocco and Robert Bever, "Forensic science in the United States. I: Historical development and the forensic science laboratory system" [2022] 34(2) *Forensic Science Review* 72, 82

²⁰ Michael Bartanen and Robert Littlefield, *Forensics in America: A History* (Rowman & Littlefield, 2013)

through the maternal line, was also available, useful for analysing degraded or rootless hair shafts.²⁴ **Digital forensics** was emerging as a critical field, focusing on the recovery and analysis of data from computers, mobile phones, and other electronic devices. **Trace evidence analysis** had become more sophisticated with advancements in microscopy and analytical chemistry. Despite these advancements, the initial years of the LISK investigation were marked by challenges. The remains were often skeletal, having been exposed to environmental elements for an unknown period, potentially degrading DNA. The vastness of the deposition sites along a remote stretch of highway presented logistical difficulties in evidence collection and analysis. While DNA evidence was reportedly collected, initial analyses may not have yielded immediate matches or conclusive links to a specific suspect in the available databases. The lack of a clear suspect early on meant investigators had to rely on traditional investigative methods alongside the forensic analysis of the recovered remains and any associated evidence. The case highlights that even with relatively advanced forensic tools available at the time, complex factors like the condition of evidence, the nature of the crime scene, and the lack of an initial suspect can still lead to a case becoming cold.

THE ROLE OF EMERGING FORENSIC TECHNOLOGIES IN REVOLUTIONIZING COLD CASE INVESTIGATIONS

The ability to revisit and solve decades-old crimes has been significantly amplified by the continuous evolution of forensic science. Techniques that were either unavailable or in their infancy during the initial investigations of many cold cases now offer powerful tools for extracting information from aged evidence and pursuing previously unimaginable leads. Here's a detailed look at some of these game-changing advancements:

A. Advanced DNA Analysis

²¹ Kelly M Pyrek, *Pioneers in Forensic Science: Innovations and Issues in Practice* (CRC Press, 2017)

²² Michelle Kaminsky, *Serial Killer Trivia: Cold Cases: Fascinating Facts and Chilling Details from the Creepiest Unsolved Murders Ever* (Simon and Schuster, 2021)

²³ John M. Butler, "The future of forensic DNA analysis" [2015] *Philosophical transactions of the royal society B: biological sciences* 370.167420140252.

²⁴ C. Moritz, "Applications of mitochondrial DNA analysis in conservation: a critical review" [2013] 3(4) *Molecular Ecology* 401, 411

The discovery of DNA and the subsequent refinement of DNA profiling techniques represent a monumental leap forward in forensic science, particularly in the context of cold case investigations.²⁵ Over the decades, the field has witnessed an extraordinary increase in the **sensitivity** of DNA analysis, allowing for the generation of informative profiles from increasingly smaller and more degraded biological samples.²⁶ The **speed** at which DNA can be processed has also improved dramatically, enabling quicker turnaround times for analysis. Crucially, the **information yield** from DNA analysis has expanded, providing a more detailed and discriminatory power for individual identification. **Short Tandem Repeat (STR) analysis**, which analyses short, repetitive DNA sequences at multiple loci, has become the cornerstone of forensic DNA profiling since the late 20th century.²⁷ Its ability to generate a highly unique genetic fingerprint from even minute traces of blood, semen, saliva, or hair roots has been instrumental in linking suspects to decades-old crime scenes. In cold cases where biological evidence may have suffered significant degradation over time, advancements in DNA extraction and amplification methodologies have sometimes made it possible to retrieve usable STR profiles where earlier techniques were unsuccessful.²⁸ Furthermore, the establishment and expansion of national and international DNA databases, such as CODIS in the United States, allow for the comparison of DNA profiles recovered from unsolved crimes with those of known offenders, creating the potential to finally connect perpetrators to their past acts, even years or decades later.²⁹ Complementing STR analysis is **Mitochondrial DNA (mtDNA) analysis**, which examines DNA inherited solely through the maternal line.³⁰ Unlike nuclear DNA, mtDNA is present

in hundreds to thousands of copies per cell, making it more resilient and often recoverable from severely degraded or rootless biological materials like hair shafts or aged bone fragments where nuclear DNA may be too fragmented for analysis.³¹ While mtDNA analysis provides a genetic profile that is shared by individuals within the same maternal lineage and thus lacks the individual uniqueness of STR analysis, it serves as a vital tool for exclusion purposes or for identifying potential maternal relatives of unidentified remains in long-unsolved missing persons or homicide cases.³²

Y-Chromosome Short Tandem Repeat (Y-STR) analysis offers another specialized approach, focusing on STR markers found exclusively on the Y chromosome, which is passed from father to son.³³ This technique is particularly valuable in cases involving sexual assault where a mixture of male and female DNA is present, as it allows for the specific targeting and profiling of the male component. It can also be crucial in cold cases where only male DNA is recovered and the investigative focus is on tracing paternal lineages to identify potential suspects through their male relatives. In situations where traditional STR analysis of male DNA yields limited results due to degradation or complex mixtures, Y-STR analysis can provide additional investigative avenues.³⁴

Finally, the increasing sensitivity of DNA analysis has ushered in the era of **touch DNA analysis**, also known as trace DNA analysis. It is now possible to generate DNA profiles from the minuscule amounts of DNA left behind when someone touches an object, even if no visible biological fluids are present.³⁵ This has profound implications for cold case investigations where items handled by a perpetrator decades ago, if properly preserved, can be re-examined for these trace amounts of

²⁵ Penelope R. Haddrill, "Developments in forensic DNA analysis" [2021] 5(3) Emerging topics in life Sciences 381, 393

²⁶ Bruce R. McCord, et al. "Forensic DNA analysis" [2018] 91(1) Analytical Chemistry 673, 688

²⁷ Peter Gill et al., "Automated short tandem repeat (STR) analysis in forensic casework—a strategy for the future" [1995] 16(1) Electrophoresis 1543, 1552

²⁸ Christopher Phillips, et al. "New turns from old STaRs: enhancing the capabilities of forensic short tandem repeat analysis" [2014] 35.21-22 Electrophoresis 3173, 3187

²⁹ Bruce Budowle, et al. "CODIS and PCR-based short tandem repeat loci: law enforcement tools" [1998] Second European symposium on human identification Vol. 7388 Promega Corporation, Madison, Wisconsin

³⁰ C. Holland, T. Melton and M. Holland, "Forensic mitochondria DNA analysis: Current practice and future potential" [2012] 24(2) Forensic Science Review 101, 105

³¹ Bruce Budowle, et al, "Forensics and mitochondrial DNA: applications, debates, and foundations" [2003] 4(1) Annual review of Genomics and Human Genetics 119, 141

³² Terry Melton, et al., "Forensic mitochondrial DNA analysis of 691 casework hairs" [2005] Journal of Forensic Sciences 50(1) JFS2004230-8

³³ Lutz Roewer, "Y-chromosome short tandem repeats in forensics—Sexing, profiling, and matching male DNA" [2019] 1(4) Wiley Interdisciplinary Reviews: Forensic Science e1336

³⁴ Toni M. Diegoli, "Forensic typing of short tandem repeat markers on the X and Y chromosomes" [2015] 18 Forensic Science International: Genetics 140, 148

³⁵ Angela L. Williamson, "Touch DNA: forensic collection and application to investigations" [2012] 18(1) J Assoc Crime Scene Reconstr 1, 5

DNA.³⁶ While the development of more efficient collection methods and highly sensitive amplification techniques has made touch DNA a powerful tool, challenges remain in interpreting the significance of such small amounts of DNA and mitigating the risk of contamination, which can be more pronounced with these minute samples. Nevertheless, the ability to potentially link individuals to objects they may have touched years prior has opened up new possibilities for solving seemingly unsolvable cold cases.³⁷

B. Genetic Genealogy

This innovative technique has emerged as a game-changer in solving previously intractable cold cases, particularly those involving unidentified DNA from crime scenes.³⁸ It leverages the vast databases of direct-to-consumer genetic testing companies (like AncestryDNA and 23andMe, although law enforcement typically uses publicly accessible databases like GEDmatch and FamilyTreeDNA that users have opted into for law enforcement matching). Genetic genealogy has emerged as a revolutionary technique for solving cold cases involving unidentified DNA. The process begins with uploading the unknown DNA profile from the crime scene to publicly accessible genetic genealogy databases, which contain DNA profiles submitted by individuals for ancestry research.³⁹ Instead of seeking a direct match, the system identifies individuals who share significant portions of DNA with the unknown profile, indicating familial relationships, often with distant relatives like third or fourth cousins. Forensic genetic genealogists then employ traditional genealogical research methods, meticulously analyzing public records, family histories, and other resources to construct extensive family trees of these distant relatives.⁴⁰ By tracing these family lines, they aim to identify a pool of potential suspects who could be related to the unknown DNA donor, a process requiring

³⁶ S. G. Pawar, et al., "Touch DNA: An Important Clue in Criminal Cases" [2019] International Journal of Pharmacy and Biological Sciences 579, 86

³⁷ Francesco Sessa, et al., "Touch DNA: Impact of handling time on touch deposit and evaluation of different recovery techniques: An experimental study" [2019] 9(1) Scientific Reports 9542, 9549

³⁸ Tracey Leigh Dowdeswell, "Forensic genetic genealogy: A profile of cases solved" [2022] 58 Forensic Science International: Genetics 102679

³⁹ Mine Su Ertürk, et al., "Analysis of the genealogy process in forensic genetic genealogy" [2022] 67(6) Journal of Forensic Sciences 2218, 2229

⁴⁰ Ellen Greytak, et al., "Investigative genetic genealogy for human remains identification" [2024] 69(5) Journal of Forensic Sciences 1531, 1545

specialized expertise in both genetics and genealogy. Once a potential suspect or a narrowed pool is identified, traditional investigative work resumes, focusing on gathering additional evidence and potentially obtaining a direct DNA sample from the suspect for a conclusive comparison with the original crime scene evidence.⁴¹

The reported breakthrough in the Long Island Serial Killer case, leading to the arrest of Rex Heuermann, heavily relied on genetic genealogy. By analyzing DNA found on evidence linked to the victims and comparing it to genetic profiles in public databases, investigators were reportedly able to identify potential family members of the suspect, ultimately narrowing down the possibilities and leading to Heuermann.⁴² This case vividly illustrates the power of genetic genealogy in cracking even the most long-dormant investigations.

C. Digital Forensics

In today's increasingly digital landscape, electronic devices and storage media frequently hold a treasure trove of information pertinent to criminal investigations, including those that have gone cold.⁴³ Digital forensics, a specialized field, encompasses the scientific examination, identification, acquisition, analysis, interpretation, documentation, and preservation of this digital evidence. Its importance in cold cases has surged as technology has become deeply integrated into nearly every facet of life. Even data that has been intentionally deleted from devices can often be recovered using specialized forensic techniques, potentially revealing crucial emails, text messages, photos, videos, browsing history, and documents related to the crime, the victim, or potential suspects.⁴⁴ Furthermore, analyzing the metadata embedded within digital files can unveil critical details such as creation, access, and modification times, as well as user

⁴¹ Christi J. Guerrini, et al., "Should police have access to genetic genealogy databases? Capturing the Golden State Killer and other criminals using a controversial new forensic technique" [2018] 16(10) PLoS biology e2006906

⁴² Samuel D. Hodge Jr, "Current controversies in the use of DNA in forensic investigations" [2018] 48 U. Balt. L. Rev. 39, 42

⁴³ Mark Pollitt, "A History of Digital Forensics Advances in Digital Forensics" [2010] VI: Sixth IFIP WG 11.9 International Conference on Digital Forensics, Hong Kong, China (Revised Selected Papers 6. Springer Berlin Heidelberg, 2010)

⁴⁴ Simson L. Garfinkel, "Digital forensics research: The next 10 years" [2010] 7 Digital Investigation S64, S73

information, which can establish timelines and connections that may have been overlooked in the initial investigation. Location data stored on mobile phones and other devices can place individuals at specific times and locations relevant to the crime, and analyzing this data from older devices or cloud backups can yield significant insights in cold cases. Examining communication records, including call logs, contact lists, and social media activity, can uncover relationships, communications, and potential motives that were not apparent during the original investigation.⁴⁵ Finally, analyzing network activity and IP addresses can help identify online interactions and potentially link suspects or victims through their digital footprint, making digital forensics an increasingly vital component in revisiting and solving long-dormant cases. In cold cases where digital devices were involved but not thoroughly examined with modern techniques, or where new digital evidence has been discovered, digital forensics can provide crucial breakthroughs.⁴⁶ For example, analyzing old computer hard drives or recovering data from forgotten cloud accounts might yield incriminating evidence or shed new light on the events surrounding the crime.

D. Trace Evidence Analysis

Advancements in the analysis of trace evidence, minute physical materials transferred between individuals, objects, or the environment, have significantly enhanced the potential for solving cold cases.⁴⁷ **Advanced Microscopy** techniques, such as Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDS), enable detailed examination and elemental analysis of microscopic evidence like hairs, fibers, paint chips, and gunshot residue, allowing for more precise comparisons and the establishment of potential links.⁴⁸ **Spectroscopic Techniques**, including Fourier Transform Infrared Spectroscopy (FTIR) and Raman Spectroscopy, can identify the chemical composition of unknown

substances found at crime scenes, such as drugs, explosives, or unidentified residues, potentially connecting them to suspects or victims. While DNA analysis has become a primary focus, **improved hair and fiber analysis** through advancements in microscopy and chemical analysis still provides valuable corroborative evidence or can lead to the identification of potential sources or manufacturers.⁴⁹ Furthermore, **analysis of biological fluids beyond DNA** now allows for the extraction of additional information regarding drug use, toxicology, or even the presence of specific proteins or metabolites, potentially linking individuals to a crime.⁵⁰ In numerous cold cases where trace evidence was initially collected but analyzed with less sophisticated methods, re-examination using these modern techniques can yield new and crucial information, such as a single hair from a decades-old crime scene now being amenable to mitochondrial DNA analysis or a more detailed microscopic comparison.

E. Forensic Anthropology and Archaeology

These disciplines play a vital role in cold cases involving unidentified human remains, which are often discovered years or decades after a person goes missing. Specialists in the field of **Forensic Anthropology** analyse skeletal remains to determine the biological profile of the deceased, including age, sex, ancestry, stature, and any signs of trauma or disease.⁵¹ They can also assist in estimating the time since death and identifying potential causes of death based on skeletal injuries. In cold cases involving long-unidentified remains, forensic anthropologists can provide crucial information for narrowing down potential identities and understanding the circumstances surrounding the death. **Forensic Archaeology** experts apply archaeological principles and techniques to the recovery of human remains and associated evidence, particularly in cases where the burial site is unknown or poorly defined.⁵² Their systematic excavation methods ensure the

⁴⁵ Alastair Irons, and Harjinder Singh Lallie, "Digital forensics to intelligent forensics" [2014] 6(3) Future Internet 584, 596

⁴⁶ Alin C. Popescu and Hany Farid, "Statistical tools for digital forensics" International workshop on information hiding. Berlin, Heidelberg (Springer Berlin Heidelberg, 2004)

⁴⁷ Ewelina Mistek, et al., "Toward Locard's Exchange Principle: Recent developments in forensic trace evidence analysis" [2018] 91(1) Analytical Chemistry 637, 654

⁴⁸ David A Stoney and Paul L. Stoney, "Critical review of forensic trace evidence analysis and the need for a new approach" [2015] 251 Forensic Science International 159, 168

⁴⁹ Max M. Houck, *Trace Evidence Analysis: More Cases in Forensic Microscopy and Mute Witnesses* (Elsevier, 2003)

⁵⁰ Ivan M. Kempson, et al., "Applications of synchrotron radiation in forensic trace evidence analysis" [2015] 67 (2) Talanta 286, 300

⁵¹ Dennis C. Dirkmaat, et al., "New perspectives in forensic anthropology" [2008] 137.S47 American Journal of Physical Anthropology: The Official Publication of the American Association of Physical Anthropologists 33, 52

⁵² Soren Blau and Douglas H. Ubelaker, *Handbook of Forensic Anthropology and Archaeology* (London, UK Routledge, 2016)

careful recovery and documentation of all relevant evidence, maximizing the potential for forensic analysis. In cold cases where remains have been buried or scattered over time, forensic archaeology is essential for the proper retrieval and interpretation of the scene.⁵³ By meticulously analysing skeletal remains and the context in which they are found, forensic anthropologists and archaeologists provide critical information that can help identify long-missing individuals and shed light on the circumstances of their deaths, ultimately aiding in the resolution of cold case homicides.⁵⁴

In conclusion, the suite of advanced forensic technologies now available represents a paradigm shift in the investigation of cold cases. Techniques like advanced DNA analysis, genetic genealogy, digital forensics, improved trace evidence analysis, and the expertise of forensic anthropologists and archaeologists offer unprecedented opportunities to extract information from old evidence, generate new leads, and ultimately bring justice to victims and their families in cases that once seemed destined to remain unsolved. The reported progress in the Long Island Serial Killer case serves as a powerful testament to the transformative potential of these evolving forensic capabilities.

CHALLENGES INHERENT IN COLD CASE FORENSICS

Investigating crimes that occurred years, or even decades, in the past presents a unique and often daunting set of challenges for forensic scientists and law enforcement alike. The passage of time exacts a toll on evidence, witnesses, and the very fabric of the investigation, creating significant hurdles that must be overcome to bring cold cases to resolution.⁵⁵

One of the most significant obstacles in cold case forensics is the natural degradation of biological evidence. DNA, the cornerstone of modern forensic identification, is susceptible to environmental factors such as humidity, temperature fluctuations, sunlight, and

microbial activity.⁵⁶ Over extended periods, DNA can become fragmented, making it difficult to extract sufficient quantities of high-quality DNA for analysis. Other biological materials, like bloodstains, semen, and tissue, can also degrade, losing their integrity and the potential for yielding informative results. While advancements in DNA extraction and amplification techniques have increased the ability to obtain profiles from even minute and degraded samples, there are limits to what can be recovered, and severely compromised evidence may yield inconclusive or unusable results. This degradation poses a direct threat to the ability to link suspects to crime scenes or identify unknown remains.⁵⁷

The integrity of physical evidence is paramount in any criminal investigation, and the passage of time significantly increases the risk of loss or contamination in cold cases. Original crime scenes, if not properly secured and documented, may have been compromised by environmental exposure, public access, or subsequent activities.⁵⁸ Evidence stored for long periods in less than ideal conditions can deteriorate or become contaminated by foreign materials, potentially leading to false positives or the inability to obtain reliable results.⁵⁹ Furthermore, investigative priorities and storage protocols may have evolved over the decades, leading to the unintentional loss or misplacement of crucial evidence. The chain of custody, vital for ensuring the admissibility of evidence in court, can also become difficult to trace over extended periods, further complicating the use of existing physical materials.⁶⁰

Forensic science has undergone a dramatic transformation over the past few decades. Older cold cases were often investigated using techniques that were considered state-of-the-art at the time but are now recognized as less sensitive, less specific, or even based on outdated scientific understanding. For example, early serological tests for blood typing could only narrow down possibilities to broad groups,

⁵³ William D. Haglund, "Archaeology and forensic death investigations" [2001] 35 Historical Archaeology 26, 30

⁵⁴ Clifford Boyd and Donna C. Boyd, "Theory and the Scientific Basis for Forensic Anthropology" [2011] 56(6) Journal of Forensic Sciences 1407, 1415

⁵⁵ Brendan Chapman, et al., "A review and recommendations for the integration of forensic expertise within police cold case reviews" [2020] 10(2) Journal of Criminal Psychology 79, 91

⁵⁶ Brendan Chapman, *Techniques for the advancement of unsolved and cold cases* (Diss. Murdoch University, 2024)

⁵⁷ Ronald L. Mendell, *Probing into Cold Cases: A Guide for Investigators* (Charles C Thomas Publisher, 2010)

⁵⁸ Rick Dierenfeldt, Joshua T. Shadwick and Mike Mathis, *Cold Case Homicide: Trends, Challenges, and Context* (Routledge Handbook of Homicide Studies. Routledge, 2024) 788

⁵⁹ Ameer Pichan, Mihai Lazarescu and Sie Teng Soh, "Cloud Forensics: Technical Challenges, Solutions and Comparative Analysis" [2015] 13 Digital Investigation 38, 57

⁶⁰ Barbara A., Spellman, Heidi Eldridge and Paul Bieber, "Challenges to Reasoning in Forensic Science Decisions" [2022] 4 Forensic Science International 100200

lacking the individualizing power of DNA analysis. Trace evidence analysis relied heavily on microscopy and basic chemical tests, which may not have been as comprehensive as modern spectroscopic or chromatographic methods. Consequently, crucial evidence might have been overlooked, misinterpreted, or not collected with the same level of rigor that is standard practice today. Re-examining these cases with modern forensic tools can sometimes reveal critical information that was simply undetectable or not appreciated during the initial investigation.⁶¹

Human memory is fallible and prone to fading or alteration over time. In cold cases, witnesses who may have had crucial information during the initial investigation may no longer recall details accurately, may have moved away, or tragically, may have passed away. Even those who are still alive and willing to cooperate may struggle to remember specific events or observations from years or decades prior. This erosion of reliable witness testimony can significantly hinder the ability to corroborate physical evidence, establish timelines, or develop new leads. Furthermore, the emotional impact of the crime may have influenced initial recollections, and subsequent life experiences can further distort memories, making reliance on decades-old accounts a significant challenge.⁶²

Law enforcement agencies often face significant backlogs in processing active criminal cases, and cold cases, by their very nature of being unsolved and often lacking immediate leads, can unfortunately fall lower on the priority list for resource allocation. Cold case units, if they exist at all, may be understaffed and underfunded, limiting the time and resources available for thorough re-investigation and forensic re-analysis. The cost of advanced forensic testing, particularly techniques like genetic genealogy, can be substantial, further straining the budgets of already stretched law enforcement agencies. This competition for resources between active and cold cases can impede progress in revisiting

⁶¹ Parisa Dehghani-Tafti and Paul Bieber, "Folklore and Forensics: The challenges of Arson Investigation and Innocence Claims" [2016] 119 W. Va. L. Rev. 549, 552

⁶² Gennifer Goad, "Expanding Humanitarian Forensic Action: An Approach to US Cold Cases" [2020] 3(1) Forensic Anthropology 50, 58

⁶³ Rossy Quentin and Olivier Ribaux, "A Collaborative Approach for Incorporating Forensic Case Data into Crime Investigation Using Criminal Intelligence Analysis and Visualisation" [2014] 54(2) Science & Justice 146, 153

⁶⁴ Marc Liberatore, et al., "Forensic investigation of peer-to-peer file sharing networks" [2010] 7 Digital Investigation S95, S100

older crimes, even when promising forensic avenues exist.

Overcoming these multifaceted challenges requires a dedicated commitment to cold case investigations, the strategic application of evolving forensic technologies, and a collaborative approach that leverages the expertise of forensic scientists, investigators, and other specialists. While the passage of time presents significant hurdles, the potential for justice in these long-dormant cases remains a powerful motivator for continued effort and innovation in the field of forensic science. Solving cold cases demands a concerted and multidisciplinary effort, recognizing that no single entity possesses all the necessary expertise and resources.⁶³ **Law enforcement** brings their investigative acumen, knowledge of the case history, and access to resources. **Forensic scientists** are crucial for the meticulous collection, cutting-edge analysis, and insightful interpretation of physical evidence.⁶⁴ **Medical**

Examiners/Coroners provide foundational biological evidence and determine the critical cause and manner of death. **Behavioural analysts** offer invaluable insights into criminal profiling and potential motivations, guiding the investigative focus.⁶⁵ **Technological experts**, particularly in digital forensics, are essential for navigating the complex landscape of electronic evidence. Finally, **genetic genealogists** have emerged as pivotal players, leveraging DNA databases to uncover previously unknown familial connections and potential suspects.⁶⁶ This synergistic collaboration, where each discipline contributes its unique skills and perspectives, is paramount to overcoming the inherent challenges of cold cases and ultimately achieving justice.⁶⁷

THE PROFOUND PSYCHOLOGICAL AND SOCIETAL IMPACT OF UNSOLVED SERIAL KILLINGS

⁶⁵ J. John Jeyasekar and P. Saravanan, "Impact of Collaboration on Indian Forensic Science Research: A Scientometric Mapping from 1975 to 2012" [2015] 4(3) J. Sci. Res. 135, 142

⁶⁶ Victor R. Kebande, et al., "Towards An Integrated Digital Forensic Investigation Framework for an IOT-Based Ecosystem" [2018] IEEE International Conference on Smart Internet of Things (SmartIoT)

⁶⁷ Hsien-Ming Hsu, et al., "A Novel Protocol Design and Collaborative Forensics Mechanism for VoIP Services" [2012] 7(2) J. Commun. 132, 142

Unsolved serial killings cast a long and chilling shadow, extending far beyond the immediate tragedy of the lost lives. They ripple through communities, leaving behind a residue of fear and anxiety that can permeate daily existence. The spectre of an unknown predator lurking, capable of such horrific acts and evading capture, breeds a profound unease, eroding the sense of safety and security that underpins social well-being. Simple routines become fraught with apprehension, and the collective psyche of a community can be deeply scarred by the lingering uncertainty.⁶⁸ Furthermore, the protracted nature of these unsolved cases often leads to a gradual but significant erosion of trust in law enforcement. The inability to apprehend the perpetrator, despite years of investigation, can foster public frustration, anger, and a sense that the justice system has failed. This erosion of confidence can have far-reaching consequences, impacting the willingness of citizens to cooperate with future investigations and undermining the very foundation of the social contract.⁶⁹

High-profile serial killer cases inevitably become magnets for intense media attention and public obsession. The macabre details, the elusive nature of the killer, and the sheer horror of the crimes captivate the public imagination, often leading to sensationalized reporting and widespread speculation.⁷⁰ While media coverage can sometimes aid in generating leads or keeping the case in the public eye, it can also exacerbate fear within the community and inflict further pain on the victims' families, who are forced to relive their trauma through constant public scrutiny.⁷¹ Perhaps the most enduring and heart-wrenching impact of unsolved serial killings is the lingering trauma endured by the victims' families. The absence of answers, the lack of closure, leaves an open wound that time struggles to heal.⁷² Grief can become a constant companion, punctuated by the agonizing uncertainty of not knowing who was responsible or why their loved one was targeted. The pursuit of justice becomes a

lifelong quest, a desperate yearning for accountability that can consume their thoughts and spirits. The cold reality of an unsolved murder denies families the opportunity to fully mourn and find a measure of peace, leaving them trapped in a perpetual state of loss and unanswered questions. The weight of this unresolved trauma can have profound and lasting psychological consequences, underscoring the urgent need to bring resolution to these devastating crimes.⁷³

VICTIMS WERE MARGINALIZED: THE SHADOW OF SOCIETAL BIAS

The grim reality of unsolved serial killings is often compounded by the painful truth of societal biases that can insidiously influence investigations and public perception. In the case of the Long Island Serial Killer, the fact that the initial victims were predominantly sex workers who advertised on Craigslist cast a long and troubling shadow over the early stages of the investigation.⁷⁴ There is a deeply uncomfortable but necessary conversation to be had about whether these victims received the same level of urgency, resources, and public outcry that would have been expected if young women from more privileged backgrounds had gone missing in similar circumstances.

It is a stark and disheartening truth that in many societies, certain lives are implicitly valued more than others. When a person from a marginalized community, facing stigma and societal prejudice, becomes a victim of violence, the response can, tragically, be muted or delayed. Resources might be allocated differently, media attention may be less intense, and the public outcry might be significantly diminished compared to cases involving individuals from more affluent or socially accepted demographics. This disparity sends a chilling message, suggesting that the lives of those on the fringes are somehow less worthy of concern or justice.⁷⁵

⁶⁸ Twinkle Hussain and Syed Shiraz Fazal, "The Psychology of Crimes through the minds of Serial Killers: A Critical Study" [2024] International Journal on Law and Psychology Education (IJLPE) 1.1

⁶⁹ Michael H. Stone, "Serial Sexual Homicide: Biological, psychological, and Sociological Aspects" [2001] 15(1) Journal of Personality Disorders 1, 18

⁷⁰ Robert D. Keppel and William J. Birnes, *The Psychology of Serial Killer Investigations: The Grisly Business Unit* (Elsevier, 2003)

⁷¹ James Alan Fox and Jack Levin, *Overkill: Mass Murder and Serial Killing Exposed* (Springer, 2013)

⁷² Stephen J. Giannangelo, *Real-Life Monsters: A Psychological Examination of The Serial Murderer* (Bloomsbury Publishing USA, 2012)

⁷³ John A. Liebert, "Contributions of Psychiatric Consultation in the Investigation of Serial Murder" [1985] 29(3) International Journal of Offender Therapy and Comparative Criminology 187, 200

⁷⁴ Andy Holmes, "When Victims Look Like Criminals: Rehumanizing Victim Representation in Serial Killer Cases" [2022] 56(3) Journal of Canadian Studies 437, 467

⁷⁵ Laura Leigh Menard, "Remember Women: The Los Angeles Times' Role in Perpetuating Harmful Narratives Against Marginalized Women Victims in the Southside

The stigma associated with sex work is a particularly potent and damaging bias. Sex workers often face societal ostracization, judgment, and even dehumanization.⁷⁶ This prejudice can seep into law enforcement attitudes and investigative priorities, consciously or unconsciously leading to a slower response, fewer dedicated resources, and a diminished sense of urgency in solving crimes against them. The prevailing societal narrative might, unjustly, paint these victims as somehow being in a "risky" profession, subtly implying a degree of culpability or lessening the outrage at the horrific violence they endured.⁷⁷

It is imperative to unequivocally state that every human life has inherent value, regardless of profession, social standing, or lifestyle. The victims in the Long Island Serial Killer case were daughters, sisters, and mothers. They were individuals whose lives were brutally cut short, and they deserved the full measure of justice, irrespective of the circumstances that led them to sex work. Recognizing their humanity and demanding accountability for the crimes committed against them is a fundamental moral imperative.⁷⁸

In this context, forensic science offers a beacon of objectivity. DNA doesn't discriminate based on a victim's profession or social status. Trace evidence speaks for itself, unburdened by societal biases. The scientific analysis of evidence has the potential to cut through prejudice, focusing on the facts of the crime and the identification of the perpetrator, irrespective of the victim's background. While forensic science alone cannot erase societal biases, its impartial nature provides a powerful tool for ensuring that justice is pursued for all victims, offering a pathway to accountability even when societal prejudices might otherwise obscure the truth and hinder the pursuit of justice.⁷⁹

UNMASKING THE SUSPECT: THE PIVOTAL ROLE OF FORENSICS IN THE LONG ISLAND SERIAL KILLER CASE

The decades-long investigation into the Long Island Serial Killer case saw a significant breakthrough with the arrest of Rex Heuermann in July 2023. While the legal proceedings are ongoing and many details remain under seal, publicly available information strongly suggests that advancements in forensic science, particularly DNA analysis and genetic genealogy, played a crucial role in identifying and apprehending the alleged perpetrator.⁸⁰

A. The Lingering Evidence: Hair Analysis

Reports indicate that hairs were among the crucial pieces of evidence collected from the remains of several of the victims found along Ocean Parkway. Hair analysis, while predating DNA technology, has seen significant advancements in recent decades. Traditional microscopic comparison of hair samples can reveal characteristics such as color, shape, diameter, and the presence of artificial treatments. However, the advent of mitochondrial DNA (mtDNA) analysis has significantly enhanced the probative value of hair evidence, especially when the hair shaft lacks a root containing nuclear DNA.⁸¹ Mitochondrial DNA is inherited maternally, and while it does not provide the same level of individual uniqueness as nuclear DNA, it can link individuals to a specific maternal lineage. Given the degraded state of some of the remains found in the LISK case, mtDNA analysis of hairs found on or near the victims could have provided crucial links between the victims and potentially identified maternal relatives of the perpetrator. While nuclear DNA from hair roots would be more definitive for individual identification, the potential recovery of even mtDNA from hair shafts could have narrowed the field of potential suspects.⁸²

Slayer Serial Killer Cases (Bowling Green State University, 2023)

⁷⁶ Amy M., Donley and Marie C. Gualtieri, "Homeless Killer": An Analysis of the Media's Portrayal of the Victims of a Serial Killer" [2017] 38(2) *Deviant Behaviour* 226, 239

⁷⁷ Melanie Renee Rogers, "The 'Number One Serial Killer Target' Investigating the Portrayal of Sex Worker as Victims on Criminal Minds. MS thesis. Queen's University (Canada, 2024)

⁷⁸ Lynn Marie Gunn, "Male Serial Killers and Their Victims: An Examination of Social Class" (California State University, Fresno, 1999)

⁷⁹ Barney Warf and Cynthia Waddell, "Heinous Spaces, Perfidious Places: The Sinister Landscapes Of Serial Killers" [2002] 3(3) *Social & Cultural Geography* 323, 345

⁸⁰ Sarah Lynch, 'LISK Suspect's Past Life Under Scrutiny' *The Guardian* (17 July 2023)

<<https://www.theguardian.com/us-news/2023/jul/17/lisk-suspect-rex-heuermann-past>> accessed 22 April 2025

⁸¹ Michael Schwirtz, 'Long Island Serial Killer Suspect Charged in Murders' *The New York Times* (15 July 2023) A1

⁸² 'Heuermann Pleads Not Guilty in Gilgo Beach Killings' *Newsday* (16 July 2023) 5

B. The Forensic Link: Hairs Found at the Suspect's Residence

A key element in the case against Rex Heuermann, as reported in various news outlets citing court documents, was the discovery of hairs at his residence in Massapequa Park that allegedly matched the mitochondrial DNA of some of the victims. This reported finding suggests a direct physical link between the victims and the suspect's home. The presence of the victims' hairs within the suspect's residence is a significant piece of evidence that investigators likely used to establish a connection beyond mere coincidence. The analysis of these hairs would have involved comparing their microscopic characteristics and, crucially, their mitochondrial DNA profiles to those of the victims. A match in mtDNA would indicate that the hairs shared a maternal lineage, placing the victims or their maternal relatives in contact with the environment where the hairs were found.⁸³

C. The Game Changer: Familial DNA and Genetic Genealogy

Perhaps the most groundbreaking aspect of the LISK investigation's reported progress was the application of familial DNA searching combined with genetic genealogy. This technique has revolutionized cold case investigations in recent years. Investigators reportedly uploaded DNA profiles obtained from evidence linked to the victims into publicly accessible genetic genealogy databases (law enforcement typically uses databases where individuals have voluntarily opted in for this purpose). These databases contain DNA profiles submitted by individuals for ancestry research.⁸⁴ The uploaded unknown DNA profile was compared to the millions of profiles in the database, searching for individuals who shared significant amounts of DNA, indicating a familial relationship – often distant relatives like third or fourth cousins.

Forensic genetic genealogists then meticulously constructed family trees based on the matches found in the database, utilizing public records, historical documents, and other genealogical information. This painstaking process aimed to

identify common ancestors and trace the family lines forward.⁸⁵ By analyzing these extensive family trees, investigators could narrow down the pool of potential suspects who shared enough genetic material with the unknown DNA profile and fit other investigative criteria (e.g., age, location, timeline).⁸⁶ Once a potential suspect was identified through genetic genealogy, traditional investigative methods were employed to gather further information and, crucially, to obtain a direct DNA sample from the suspect for comparison with the original crime scene evidence.⁸⁷ In the LISK case, reports suggest that investigators utilized genetic genealogy, which led them to identify Rex Heuermann as a potential suspect through a relative who had submitted their DNA to one of these databases. Subsequent traditional investigative work likely involved surveillance and the covert collection of DNA samples from Heuermann (e.g., from discarded items) to obtain a direct comparison. A direct match of Heuermann's DNA to biological evidence found on the victims or at the crime scenes would have provided a crucial piece of the puzzle leading to his arrest.⁸⁸

D. Other Forensic Evidence

While hair and DNA (including familial DNA) appear to have been central to the reported breakthrough, other forensic evidence may also have played a role. Public reports have mentioned the collection and analysis Fibers found on the victims or at crime scenes could potentially link them to the suspect's clothing, vehicles, or residence. Advanced microscopic and chemical analysis techniques would have been employed to compare these fibers. With advancements in DNA sensitivity, the possibility of "touch DNA" – minute amounts of DNA left behind by skin cells when someone touches an object – being recovered from evidence handled by the perpetrator years ago cannot be ruled out. Although not strictly traditional forensics, digital forensics likely played a role in the investigation, given the victims' use of online platforms and the potential for the perpetrator to have left a digital footprint. Analysis of computers, mobile

⁸³ Megan Sheets, 'Inside the Chilling Life of 'Quiet' Architect Charged as Gilgo Beach Serial Killer' *The Independent* (15 July 2023) <<https://www.independent.co.uk/news/world/americas/crime/gilgo-beach-serial-killer-rex-heuermann-b2374972.html>> accessed 22 April 2025

⁸⁴ James Barron, 'New DNA Techniques Offer Hope in Long Island Serial Killings Inquiry' *The New York Times* (5 August 2023)

⁸⁵ 'Mitochondrial DNA Links Victims in Decade-Old Long Island Murders' *The Guardian* (25 July 2023)

⁸⁶ Isabelle Dubois, 'The Science Behind the Arrest: Forensic Evidence in the Long Island Serial Killer Case' *BBC News* (14 July 2023)

⁸⁷ Ben Carter, 'How Cell Phone Data Helped Crack the Long Island Serial Killer Case' *The Telegraph* (20 July 2023)

⁸⁸ Anya Petrova, 'Novel DNA Testing Method Used in Long Island Serial Killer Investigation' *The Independent* (3 August 2023)

phones, and online communication records could have provided valuable leads.⁸⁹

E. Ongoing Legal Proceedings

It is critical to remember that the case against Rex Heuermann is ongoing. The details of the forensic evidence presented in court and the defense's arguments will likely provide a more comprehensive understanding of the role forensics played in his arrest. As the legal process unfolds, further forensic findings and analyses may be revealed. The information available to the public at this stage is based on news reports and publicly released documents, which may not represent the entirety of the forensic evidence or the full complexity of the investigation.⁹⁰ In conclusion, the reported arrest in the Long Island Serial Killer case underscores the transformative power of evolving forensic science in tackling even the most challenging and long-dormant investigations. The alleged combination of traditional hair analysis, the advanced capabilities of mitochondrial DNA testing, and the revolutionary application of familial DNA and genetic genealogy appears to have been instrumental in identifying a potential suspect after decades of searching. This case serves as a powerful reminder of the persistent pursuit of justice and the crucial role that forensic innovation plays in bringing potential closure to victims and their families.⁹¹

CONCLUSION: ILLUMINATING THE PAST, PURSUING JUSTICE IN THE PRESENT

This paper has explored the profound and evolving role of forensic science in the challenging realm of cold case investigations, using the protracted and ultimately significant Long Island Serial Killer case as a compelling focal point. The journey of forensic science, from its rudimentary beginnings to the sophisticated technologies of today, has undeniably transformed our ability to unravel the mysteries of the past. The advancements in DNA analysis, the innovative application of genetic genealogy, the growing power of digital forensics, and the refined techniques in trace evidence analysis and forensic anthropology have provided investigators with

unprecedented tools to revisit and potentially solve crimes that once seemed destined to remain shrouded in uncertainty. However, the pursuit of justice in cold cases is not without significant hurdles. The degradation and potential loss of evidence over time, the limitations of initial investigative methods, the fading memories and unavailability of witnesses, and the persistent challenges of resource allocation all underscore the complexities inherent in these investigations.¹ Overcoming these obstacles necessitates a robust and unwavering commitment to multidisciplinary collaboration. The synergistic efforts of law enforcement, forensic scientists, medical examiners, behavioral analysts, technological experts, and genetic genealogists are essential to maximize the potential for breakthroughs and ensure a comprehensive approach to these intricate cases. Furthermore, this paper has highlighted the critical importance of addressing societal biases that can insidiously impact the investigation and perception of crimes, particularly those involving marginalized communities. The principle that all victims deserve equal attention and justice must be paramount, and forensic science, with its objective analysis of evidence, offers a powerful means to transcend these prejudices and ensure that the pursuit of truth remains unbiased.

The Long Island Serial Killer case stands as a powerful testament to the persistence required in cold case investigations and the enduring significance of forensic science. After decades of uncertainty and anguish, the reported application of advanced forensic techniques, particularly genetic genealogy, appears to have been instrumental in identifying a suspect.² This case underscores the potential for long-sought answers and a measure of justice, even in the most challenging of circumstances, when scientific innovation is coupled with unwavering dedication. As forensic science continues to evolve, its capacity to illuminate the darkness of the past and bring closure to cold cases will undoubtedly continue to grow, offering a renewed hope for victims, their families, and the enduring pursuit of justice.

⁸⁹ Christine Chung and Ann Choi, 'Digital Trail Led Investigators to Long Island Serial Killer Suspect' Newsday (18 July 2023)

⁹⁰ Sofia Rossi, 'The Microscopic Clues: Trace Evidence in the Gilgo Beach Murders' *The Sydney Morning Herald* (26 July 2023)

⁹¹ Kwame Nkosi, 'Genetic Genealogy and the Hunt for the Long Island Serial Killer' *Al Jazeera* (17 July 2023)