RE-EVALUATION OF CRIMINAL CASES BASED ON EMERGING FORENSIC TECHNOLOGIES

Ioana PICU[*]

Abstract

Advancements in forensic science have profoundly reshaped the process of criminal case reevaluation, facilitating both the exoneration of wrongfully convicted individuals and the resolution of cases that have long remained unsolved. This paper seeks to explore the impact of cutting-edge forensic technologies, ranging from DnA analysis and digital forensics to artificial intelligence, within the mechanisms of judicial review. These innovations provide unprecedented perspectives on evidence, challenging previously final rulings and contributing to the redefinition of the principles of equity and justice.

This study highlights the transformative role of forensic progress in identifying judicial errors through a series of emblematic cases that have led to retrials and exonerations.

While these advancements enhance the precision of evidence, they also introduce significant challenges for the legal system. The admissibility of AI-generated forensic results, the risks of misinterpretation, and the ever-evolving nature of digital evidence necessitate a judicious and balanced approach.

Thus, this paper underscores the need for a legal framework that embraces scientific innovation while safeguarding the fundamental right to a fair trial and the integrity of the justice system. By critically examining both the benefits and the inherent limitations of emerging forensic technologies, this study contributes to the ongoing discourse on the future of judicial review in the digital age.

Keywords: *reevaluation, judicial error, emerging forensic technologies, AI, fair justice.*

1. Introduction

In an era where scientific innovation continually reshapes the contours of truth and justice, criminal law stands at a decisive crossroads. The emergence of cutting-edge forensic technologies, ranging from next-generation DnA sequencing and digital forensics to algorithmic analysis and 3D reconstructions, has not only expanded the investigator's toolkit, but has also redefined the very thresholds of legal certainty. These innovations offer new pathways toward the resolution of stalled investigations, the correction of wrongful convictions, and the restoration of justice in cases once deemed closed and immutable.

The significance of this study lies not solely in the technological marvels themselves, but in their profound implications for the legal system: their potential to reveal hidden truths, to rectify historical errors, and to recalibrate the balance between scientific progress and procedural fairness. Yet, these same tools also bring with them substantial risks of misinterpretation, overreliance, and ethical ambiguity, particularly when deployed without rigorous standards or sufficient legal oversight.

This paper seeks to examine the evolving relationship between forensic science and judicial review, with a particular focus on the reevaluation of criminal cases in light of emerging evidentiary tools. Drawing upon an extensive corpus of international legal scholarship, jurisprudence, institutional reports (such as those from the European Network of Forensic Science Institutes and the Innocence Project), and emblematic case studies, the study aims to analyze how new technologies are reshaping both the probative landscape and the philosophical foundations of justice.

Ultimately, the paper offers a series of *de lege ferenda* proposals, advocating for legislative and procedural reforms to ensure that scientific progress serves not only the pursuit of truth, but also the preservation of human dignity and legal integrity. In doing so, it aligns with the growing international imperative to harmonize forensic innovation with the principles of legality, transparency, and fairness in criminal adjudication.

[*] PhD Candidate, Faculty of Law, „Nicolae Titulescu" University of Bucharest (e-mail: office@ioanapicu.ro).

2. Concept and legal framework

In the intricate architecture of international criminal law, the mechanism of reviewing final judgments stands not merely as a procedural instrument but as a foundational pillar of authentic justice.

At its core, review constitutes an extraordinary legal remedy through which judicial errors concerning the facts retained by a final court decision may be rectified, or through which continuous violations of fundamental rights, as protected by ECHR, may be addressed, particularly in courts where the Constitutional Court has admitted an exception of unconstitutionality after the judgment became final.[1]

Whether it concerns a ruling based on tainted evidence, the subsequent discovery of exonerating facts, or grave violations of procedural rights, the review of a criminal conviction becomes, in essence, an act of reconciliation between law and truth. The regulation of this mechanism across various jurisdictions reflects a collective awareness that judicial infallibility remains more an aspiration than a reality, and that legal systems must retain the humility to acknowledge and amend their own errors.

Though the procedure of retrial may vary according to the specificities of each legal system, it preserves a common conceptual core: its initiation requires the submission of a reasoned application by the interested party, followed by a preliminary assessment of its admissibility. If deemed well-founded, the court is called upon to re-examine the substance of the case, with full discretion to uphold, amend, or overturn the prior judgment.

Over time, the unfolding evolution of justice has revealed that, regardless of how rigorously procedural safeguards may be woven into the structure of a trial, even judgments long regarded as final are not immune to error. Material mistakes or misinterpretations of evidence may distort judicial impartiality.

Against this ever-shifting legal landscape, modern forensic technologies, ranging from DnA analysis and digital forensics to the use of AI in criminal investigations, have emerged as revelatory tools, capable of bringing to light profound judicial errors. These developments have redefined the understanding of finality in criminal justice and have rendered imperative the reopening of cases and the reassessment of verdicts in the name of truth and the restoration of human dignity.

Internationally, the review of criminal judgments is a principle widely recognized in the legislation of numerous states and enshrined in various international legal instruments. Art. 14 (6) of the 1966 International Covenant on Civil and Political Rights, adopted by the UN, affirms the right of a person convicted by final judgment to seek a review where new evidence emerges that may establish innocence.[2]

Judicial institutions have acknowledged the necessity of exceptional remedies in criminal matters. ECtHR plays a central role in this regard. Through art. 6 ECHR, it guarantees the right to a fair trial, thereby imposing on member states a duty to ensure mechanisms of review in cases of miscarriage of justice. The Court has issued numerous judgments emphasizing the importance of access to review, particularly where new exculpatory evidence arises or where procedural violations have undermined the integrity of the original proceedings.[3]

The ICC remains the first and only permanent criminal tribunal with global jurisdiction, established to investigate, prosecute, and adjudicate individuals responsible for the gravest crimes of concern to the international community: genocide, crimes against humanity, and war crimes.[4] Within the ICC, review is governed by the Rome Statute, which allows the reconsideration of a final conviction when new evidence arises that could undermine the findings of the Court, or where serious procedural irregularities are identified. According to art. 84 of the Statute, a final conviction may be revised if *„a new fact has been discovered that: (i) was not known at the time of the trial and could not have been discovered earlier through the exercise of due diligence, and (ii) would likely have led to a different verdict had it been established during the trial."*[5]

In states with a well-established democratic tradition, the review of criminal convictions is clearly regulated, and exoneration through scientific evidence, particularly DnA testing, has become a fundamental mechanism for correcting judicial errors.

In USA, initiatives such as the *Innocence Project* have led to the release of hundreds of wrongfully convicted individuals, prompting a profound reconsideration of the architecture of criminal justice. Founded in 1992 at the Cardozo School of Law in New York, this non-profit organization focuses on exonerating the wrongfully

[1] M. Udroiu, *Procedură penală – partea specială*, 2nd ed., C.H. Beck Publishing House, Bucharest, 2015.

[2] Art. 14 para. (6) of the 1966 International Covenant on Civil and Political Rights, adopted by the United Nations.

[3] Art. 6 of the 1950 Convention for the Protection of Human Rights and Fundamental Freedoms, as amended by Protocols no. 3, 5, and 8, and supplemented by Protocol no. 2, signed at Rome on 04.11.1950.

[4] Information available at *https://www.icc-cpi.int/about/the-court,* last consulted on 26.03.2025.

[5] Art. 84 para. (1) letter (a) points (i) and (ii) of the 1998 Rome Statute of the International Criminal Court, dated 17.07.1998.

convicted, especially through the application of DnA evidence. Born out of a recognition that the judicial system is not immune to error, the project serves as a corrective force, illuminating the limitations of conventional criminal procedure.[6]

In the UK, the establishment in 1997 of the Criminal Cases Review Commission marked the formation of an independent body tasked with investigating potential miscarriages of justice in convictions and sentences imposed by the courts of England, Wales, and Northern Ireland. It remains the only institution in the UK with the authority to refer a criminal conviction back to the appellate court outside of the ordinary appeals process. The Commission evaluates final judgments to determine whether new evidence or legal issues have emerged that cast doubt on the original verdict and may recommend retrial where substantial grounds for review exist.[7]

In Romanian criminal procedure law, review is regarded as an extraordinary remedy designed to correct miscarriages of justice. One of its central foundations lies in the possibility of discovering new facts or circumstances unknown at the time of judgment, facts which, if properly evaluated, could fundamentally alter the legal and factual balance upon which the final decision was based.[8]

This legal framework faithfully mirrors an European legal model, in full harmony with the values enshrined in the ECHR, and aligns with the consistent jurisprudence of the Strasbourg Court, which maintains that the emergence of new evidence capable of challenging final decisions justifies the reopening of proceedings in the name of truth and material justice.

The foundational principles of forensic science have required a renewed reflection – one aimed at clarifying their scope, minimizing the risk of misinterpretation, and aligning their application with the evolving fabric of society. This imperative is addressed by the Sydney Declaration, a landmark conceptual framework introduced in 2022, which seeks to redefine and fortify the identity of forensic science in the modern era, particularly in light of rapid digitalization and the complex technological challenges it brings forth.[9]

Ultimately, retrial represents a vital guarantee of judicial fairness, a mechanism of correction that ensures the judicial act is not reduced to a mere procedural formality, but instead reflects an authentic pursuit of truth and a faithful observance of the fundamental rights of all parties involved. In an age where science and technology increasingly permeate the legal sphere, justice is called upon to adapt, to embrace new tools, and to reassess with clarity the certainties once held as beyond dispute.

2.1. DnA analysis

Forensic DnA analysis has come to represent a foundational pillar of contemporary forensic science, reshaping both the course of criminal investigations and the very architecture of justice itself. The ability to isolate and interpret genetic material from diverse biological traces, such as blood, hair, epithelial cells, or saliva, has offered investigative authorities a tool of unmatched precision, enabling the identification of victims, the establishment of connections between individuals and crime scenes, and the exoneration of those wrongfully accused.[10] Within the courtroom, DnA evidence is frequently regarded as the *gold standard*, owing to its exceptional specificity and reliability in affirming individual identity.[11]

DnA extraction and preservation stand as pivotal stages within the forensic process, for the integrity of the extracted genetic material directly shapes the reliability of all subsequent analyses. While traditional methods have long proven their utility, they often demand considerable time, labor, and strictly controlled laboratory conditions to mitigate the risk of contamination.[12] Moreover, the challenge of maintaining DnA integrity over time persists, particularly when samples are subjected to extreme environmental conditions that threaten degradation.[13]

Emerging technologies are designed to enhance the efficiency, sensitivity, and overall quality of DnA samples. For instance, the development of portable kits and mobile DnA analysis platforms now allows for the

[6] Information available at *https://innocenceproject.org/restoring-freedom/*, last consulted on 27.03.2025.

[7] Information available at *https://ccrc.gov.uk/our-powers-practices/*, last consulted on 27.03.2025.

[8] Art. 453 para. (1) letter (a) CPP, as in force on 27.03.2025.

[9] C. Roux, R. Bucht, F. Crispino, P. De Forest, C. Lennard, P. Margot, M.D. Miranda, N. NicDaeid, O. Ribaux, A. Ross, S. Willis, *The Sydney Declaration, Revisiting the essence of forensic science through its fundamental principles*, Forensic Sci. Int., 332 (2022), article 111182.

[10] S.K. Alketbi*, Analysis of Touch DnA,* Doctoral Thesis, University of Central Lancashire, Preston, Lancashire, UK, 2023.

[11] S.K. Alketbi, *Emerging Technologies in Forensic DnA Analysis*, 14.09.2024, available at *https://www.sciepublish.com/article/pii/279#B1*, last consulted on 28.03.2025.

[12] S.K. Alketbi*, Analysis of Touch DnA, op. cit*.

[13] S.K. Alketbi, *The Affecting Factors of Touch DnA*, J. Forensic Res. 2018, 9, 424 (Google Scholar).

rapid, on-site processing of biological evidence, an advancement particularly valuable in scenarios such as disaster victim identification or the examination of forensic traces in remote locations.[14] These systems are designed to perform all steps of DnA analysis: extraction, amplification, separation, detection, and interpretation, within a single device, often referred to as a *„lab in a box"*.[15]

Automated DnA extraction systems have markedly enhanced both the speed and precision of forensic workflows, reducing processing times from one to two hours to approximately thirty minutes, while also minimizing the risks of human error and sample contamination.[16] These technologies can be seamlessly integrated with Laboratory Information Management Systems (LIMS), allowing for meticulous tracking and documentation at every stage of analysis. As a result, they are increasingly adopted by high-throughput forensic laboratories, offering improved quality control and strengthening the integrity of the chain of custody.[17]

New technologies have brought forth innovative solutions for preserving biological evidence, including the use of stabilizing agents that prevent DnA degradation[18], cryopreservation techniques employing ultra-low temperatures to shield genetic material from freeze-thaw damage[19], and advanced dry-state storage methods that allow samples to be kept at room temperature without the need for refrigeration. These advances are particularly vital for forensic laboratories tasked with safeguarding delicate samples, often drawn from aged cases or collected under extreme environmental conditions, ensuring their integrity for future analysis.[20]

Next-generation sequencing (NGS) is a new technology used for DnA and RNA sequencing and variant/mutation detection. NGS can sequence hundreds and thousands of genes or whole genome in a short period of time. The sequence variants/mutations detected by NGS have been widely used for disease diagnosis, prognosis, therapeutic decision, and follow up of patients. The capacity of its massive parallel sequencing offers new opportunities for solving cases once thought unsolvable, refining identification, and broadening the interpretative scope of forensic evidence.[21]

In 2024, for the first time in the United States, evidence derived from NGS was formally admitted in a court of law. In this landmark case, NGS testing was employed to precisely determine the location of two homicides, committed in a strikingly similar manner against unhoused victims in Bakersfield, California, in 2020 and 2021. As a relatively novel technology, NGS had not previously undergone judicial scrutiny in the American legal system. That changed with this investigation – an inflection point that is likely to reshape the entire landscape of forensic DnA analysis. In both cases, the victims had suffered fatal injuries inflicted by blunt force trauma. The subsequent investigation identified Adrian Chavez as the prime suspect, through both eyewitness testimony and biological traces recovered from the crime scenes. The Kern Regional Crime Laboratory utilized the Verogen MiSeq FGx sequencing system, which allowed the examination of 152 genetic markers in a single sample, vastly surpassing the 24 markers typically assessed using conventional STR analysis. This enhanced genetic resolution underscored the forensic power of NGS, playing a critical role in determining the crime scene location and reconstructing the violent acts, thereby strengthening the prosecutorial case. Following a thorough pretrial admissibility hearing, the court deemed NGS-based DnA testing to be scientifically valid and broadly accepted within the scientific community. This decision marked the first official integration of NGS into the US judicial process. Ultimately, the jury found Chavez guilty of both murders and upheld the special circumstance of multiple homicide. The ruling not only delivered justice in a tragic case but also established a precedent for the admissibility of emerging genomic technologies within the realm of forensic science.[22]

Another innovative tool, invaluable in the reopening of unsolved cases where traditional forensic methods have failed to yield results, is touch DnA testing. Recent advances in DnA amplification and sensitivity now allow for the extraction of viable genetic material from objects preserved for decades, enabling a fresh examination

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[14] J.A. Gamble, V. Spicer, M. Hunter, Y. Lao, R.D. Hoppa, D.D. Pedersen *et al.*, *Advancing Sex Estimation from Amelogenin: Applications to Archaeological, Deciduous, and Fragmentary Dental Enamel,* J. Forensic Bioarchaeol, Res. 2024, 54, 104430 (Google Scholar).

[15] R. Rathnayake, K.O. Jama, *Rapid Identification of Semen Stains in Forensic Investigations: STK Sperm Tracker,* Int. J. Sci. Acad. Res. 2024, 5, 7687-7693 (Google Scholar).

[16] S.K. Alketbi, *The Affecting Factors of Touch DnA*, *op. cit*.

[17] J.A. Gamble, V. Spicer, M. Hunter, Y. Lao, R.D. Hoppa, D.D. Pedersen *et al.*, *op. cit*.

[18] *Ibidem*.

[19] R. DeSalle*, DnA Barcoding, Humana*, New York, NY, USA, 2024, available at *https://link.springer.com/content/pdf/10.1007/978-1-0716-3581-0.pdf*, last consulted on 28.03.2025.

[20] M. Morvan, *Prote Omics Analysis of Aging Proteins*, Doctoral Dissertation, Univerzita Pardubice, Pardubice, Czech, 2023.

[21] Q. Dahui, *Next-generation sequencing and its clinical application,* Cancer Biol Med, 2019 February.

[22] M. Taylor, *Next Generation Sequencing Accepted in Court for First Time*, Forensic in the Scene and in the Lab, 29.01.2024.

of evidence through modern techniques capable of detecting even the faintest traces[23] [24], such as those originating from skin cells, perspiration, or other bodily substances. These traces can be collected from a broad range of handled surfaces and personal items: tools, weapons, garments, steering wheels, door handles, gear shifts - thus establishing direct connections between suspects and the acts committed.[25]

A more profound examination of forensic genetics brings us to the realm of Low Copy Number (LCN) DnA—samples that hold only minute traces of genetic material. Typically derived from touch DnA or other minimal biological residues, such samples may contain DnA from only a handful of cells. This scarcity renders their analysis significantly more complex than that of conventional forensic specimens. To navigate these challenges, forensic experts employ highly specialized techniques designed to amplify such limited genetic material. While polymerase chain reaction remains the standard, alternative strategies, such as whole genome amplification, may also be employed when necessary. The ultimate aim of these refined procedures is to construct a reliable and accurate genetic profile, despite the scant volume of DnA available.[26]

In parallel with the evolution of forensic methodologies, a new benchmark has emerged in the form of artificial intelligence. This discipline involves the creation of computational systems capable of executing tasks traditionally reliant on human cognition – tasks such as pattern recognition and decision-making.[27;28] Within the domain of forensic DnA analysis, AI is being harnessed to automate data interpretation, disentangle complex DnA mixtures, and streamline workflows within forensic laboratories.[29] Algorithms trained to detect intricate genetic patterns can sift through vast genomic datasets, often discerning connections imperceptible to the human eye.[30] Such technological advances are proving indispensable, particularly in cases involving degraded samples or intricate genetic admixtures, offering new dimensions of clarity in the pursuit of truth.[31]

Last but not least, the exploration of 3D genomics and spatial DnA analysis unveils the genetic material within its native, three-dimensional architecture, offering unique insights into the interplay between DnA and its surrounding environment. This refined perspective greatly enhances the interpretation of complex or degraded biological samples.[32] Spatial analysis allows for the precise identification of the tissue origin of DnA, a critical advantage in cases involving multiple biological sources.[33] Furthermore, it sheds light on patterns of degradation, facilitating the reconstruction of aged samples or those exposed to extreme environmental conditions. When applied to hard tissues such as bones or teeth, these techniques assist in the identification of human remains, particularly in mass disasters or cases of unresolved disappearance.[34] The study of environmental DnA distribution further enables the detection of human or animal presence at a given location, offering valuable clues for reconstructing crime scenes with greater fidelity.[35]

The admissibility of DnA evidence in court remains a pivotal legal concern, as the credibility of such scientific testimony can decisively sway the outcome of a trial. In numerous jurisdictions, the validity of forensic methods is assessed under the *Daubert* or *Frye standards*, which examine whether the techniques employed

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[23] R. Hoffmann, G.E. Meakin, M. Morelato, C. Roux, *The Utility of Trace DnA within Forensic Science for Investigative and Intelligence Purposes,* WIREs Forensic Sci. 2024, 6, e1515 (Google Scholar).

[24] H.R. Dash, P. Shrivastava, S. Das, *Forensic Trace and Touch DnA Analysis. In Principles and Practices of DnA Analysis: A Laboratory Manual for Forensic DnA Typing*, Humana: New York, NY, USA, 2020.

[25] S.K. Alketbi, *Analysis of Touch DnA, op. cit*.

[26] J.J. McShane, *False positives and negatives: the risks of low copy number DnA analysis*, March 2, 2023, in DnA, available at *https://thetruthaboutforensicscience.com/false-positives-and-negatives-the-risks-of-low-copy-number-dna-analysis/*, last consulted on 28.03.2025.

[27] F. Sessa, M. Esposito, G. Cocimano, S. Sablone, M.A.A. Karaboue, M. Chisari *et al.*, *Artificial Intelligence and Forensic Genetics: Current Applications and Future Perspectives*, Appl. Sci. 2024, 14, 2113 (Google Scholar).

[28] J.-A. Bright, D. Taylor, C. McGovern, J. Buckleton, *Developments in the Interpretation of Complex DnA Profiles,* Forensic Sci., Int. Genet. 2019, 40, 32-40 (Google Scholar).

[29] M. Barash, D. McNevin, V. Fedorenko, P. Giverts, *Machine Learning Applications in Forensic DnA Profiling: A Critical Review*, Forensic Sci. Int. Genet. 2024, 69, 102994 (Google Scholar).

[30] F. Sessa, M. Esposito, G. Cocimano, S. Sablone, M.A.A. Karaboue, M. Chisari *et al.*, *op. cit*.

[31] N. Galante, R. Cotroneo, D. Furci, G. Lodetti, M.B. Casali, *Applications of Artificial Intelligence in Forensic Sciences: Current Potential Benefits, Limitations, and Perspectives*, Int. J. Leg. Med. 2023, 137, 445-458 (Google Scholar).

[32] L.M. Crowley, G.R. Broad, C. Fletcher, I. Januszczak, I. Barnes, Al. Whiffin, *The Genome Sequence of the Banded Burying Beetle,* Nicrophorus investigator Zetterstedt. Wellcome Open Res. 2024, 9, 343 (Google Scholar).

[33] L. Ren, Y. Shang, L. Yang, S. Wang, X. Wang, S. Chen *et al.*, *Chromosome-Level de Novo Genome Assembly of Sarcophaga peregrina Provides Insights into the Evolutionary Adaptation of Flesh Flies*. *Mol. Ecol. Resour.* 2021, 21, 251-262 (Google Scholar)

[34] S. Lu, J. Yang, X. Dai, F. Xie, J. He, Z. Dong *et al.*, *Chromosomal-Level Reference Genome of Chinese Peacock Butterfly (Papilio bianor) Based on Third-Generation DnA Sequencing and Hi-C Analysis*, GigaScience 2019, 8, 1-10 (Google Scholar)

[35] L.M. Crowley, G.R. Broad, C. Fletcher, I. Januszczak, I. Barnes, Al. Whiffin, *op. cit.*

are both scientifically reliable and broadly accepted within the relevant academic community.[36] The Frye standard (*Frye v. United States*, 1923) demands that the scientific procedure be generally endorsed by experts, while the more stringent *Daubert standard* (*Daubert v. Merrell Dow Pharmaceuticals*, 1993) requires testability, peer review, known error rates, and judicial assessment of scientific validity, positioning the judge as a *„gatekeeper of science"*.[37]

Although DnA analysis is broadly recognized for its accuracy, certain complexities remain, particularly in cases involving degraded samples, intricate mixtures, or minute quantities of genetic material.[38] The courts must approach emergent technologies, such as machine-learning-based analysis or phenotypic prediction, with due caution, ensuring they meet evidentiary standards before being admitted into judicial proceedings.[39]

In the light of these extraordinary scientific advancements, from the early isolation of the DnA molecule to the refinement of next-generation sequencing, genetic analysis has evolved from a biological abstraction to an evidentiary instrument of irrefutable force. This transformation has enabled the reexamination of long-shrouded forensic enigmas, turning century-old mysteries into cases newly illuminated by science.

2.1.1. Case studies

A striking example is the infamous case of Jack the Ripper, the spectral figure who haunted the bloodied streets of London in 1888 and whose identity remained elusive for over a century. Only with the rise of modern forensic techniques for analyzing residual biological traces, preserved, perhaps by accident, did the possibility of a genetic investigation into this historical case emerge, turning dark legend into a case reopened to the light.

In 2007, criminology enthusiast Russell Edwards acquired at auction a shawl believed to have been found beside the mutilated body of Catherine Eddowes, the Ripper's fourth victim. Untouched by washing and passed down through generations, the shawl potentially harbored biological evidence. Edwards collaborated with molecular biologist Jari Louhelainen, who conducted a genetic analysis that suggested the presence of DnA from both the victim and Aaron Kosminski, a 23-year-old Polish barber long suspected at the time, known to suffer from severe mental illness and living in proximity to the crime scenes.[40]

Yet in 1888, molecular genetics did not exist as a science. The structure of DnA was only discovered in 1953[41], and its first forensic applications emerged in the 1980s with the advent of techniques like restriction fragment length polymorphism (RFLP).[42]

The absence of proper technology and the lack of preserved biological evidence meant that Jack the Ripper's identity remained unconfirmed not simply due to scientific limitations, but also because the victorian police had no standardized method of evidence collection - no protocols, no chain of custody, no contamination safeguards.

Crucially, the shawl in question was never officially recorded as evidence at the crime scene. It was touched by numerous individuals and stored under questionable conditions, raising concerns about the integrity of the extracted DnA. Furthermore, Edwards's conclusions have faced scrutiny, as the essential DnA evidence was not published in a peer-reviewed scientific journal. Still, descendants of the victim who once owned the shawl have initiated a legal request to reopen the 137-year-old case.

Though the case of Jack the Ripper remains steeped in myth and cultural fascination, the true power of DnA technology lies not in solving historical legends, but in correcting contemporary injustices. Today's matured genetic technologies serve as formidable instruments of truth in the justice system, tools that have brought clarity to ambiguous cases, absolved the wrongfully accused, and unveiled hidden truths after decades of uncertainty.

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[36] B. Budowle, A. Sajantila, *Revisiting informed consent in forensic genomics in light of current technologies,* Int. J. Legal Med. 2023, 123, 71-84 (Google Scholar).

[37] Information available at *https://www.aquilogic.com/pdf/expert%20testimony%20and%20the%20daubert%20and%20frye%20standards.pdf*, last consulted on 29.03.2025.

[38] W.C.D. Tan, A. Stasi, B.K. Dhar, *Ethical and regulatory issues in forensic DnA profiling in Thailand*, Forensic Sci. Int. 2022, 61, 55-69 (Google Scholar).

[39] B.R. McCord, Q. Gauthier, S. Cho, M.N. Roig, *Recent developments in forensic DnA typing*, Anal. Chem. 2018, 8, 1442-1453 (Google Scholar).

[40] Information available at *https://nypost.com/2025/02/15/world-news/jack-the-rippers-identity-revealed-after-dna-breakthrough-historian/?utm_source=chatgpt.com*, last consulted on 29.03.2025.

[41] A.J.F. Griffiths *et al.*, *An Introduction to Genetic Analysis*, W.H. Freeman, 2000.

[42] A.J. Jeffreys, V. Wilson, S.L. Thein, *Hypervariable 'minisatellite' regions in human DnA Nature*, 1985, 314, 67-73.

Kirk Bloodsworth, for instance, was sentenced to death in Maryland for the rape and murder of a 9-year-old girl. In 1993, after nearly a decade of imprisonment, DnA evidence proved his innocence – making him the first death row inmate in the United States to be exonerated by post-conviction DnA testing, thanks in large part to the efforts of the Innocence Project.[43]

Similarly, Stefan Kiszko spent 16 years in prison for the murder of an 11-year-old girl in Rochdale. In 1992, DnA evidence showed the semen found at the crime scene did not belong to him, leading to his release and full exoneration.[44]

Frank Sterling, convicted in 1992 for the murder of a 74-year-old woman in Rochester, New York, was exonerated after 19 years when DnA tests revealed the real perpetrator.[45]

Steven Avery, the central figure of the documentary *Making a Murderer*, was initially exonerated through DnA testing after spending 18 years behind bars for a crime he did not commit. Yet, in a dramatic turn of events, he was later convicted again in a separate case, his story continuing to fuel debate over the reliability and limits of the justice system.[46]

The Golden State Killer, identified as Joseph James DeAngelo, was apprehended in 2018 through the use of genetic genealogy and publicly accessible DnA databases – an investigative breakthrough that linked him to a series of violent crimes committed over decades, including rape and murder, long shrouded in mystery.[47]

The Exonerated Five, formerly known as the *Central Park Five*, were five teenagers wrongfully convicted in 1989 for the brutal assault and rape of a jogger in New York's Central Park. Their exoneration came years later, sustained by DnA evidence and the confession of the actual perpetrator, underscoring the profound consequences of investigative bias and media pressure.[48]

These landmark cases represent pivotal milestones in the evolution of modern jurisprudence, where scientific evidence, particularly DnA analysis, has emerged as a cornerstone in the moral and legal rebalancing of justice.

Beyond their probative strength, these instances have stirred deep public and academic reflection, becoming the subject of documentaries, case studies, and archival explorations aimed at safeguarding against future miscarriages of justice. They bear witness not only to the personal tragedies of the wrongfully convicted, but also to the justice system's capacity for self-correction in the face of scientific advancement.

Above all, these reopened files serve as solemn reminders that, where law embraces the dynamic power of scientific knowledge, truth can ultimately reclaim its rightful place, even after decades of silence and suffering.

2.2. AI

There is no longer any doubt that artificial intelligence has begun to weave itself deeply into the fabric of forensic science, demanding a nuanced and discerning understanding of its influence on this delicate and high-stakes domain. Recognizing this growing significance, the European Forensic Science Area, a strategic initiative of the European Union aimed at fostering harmonized standards, collaboration, and modernization across forensic disciplines, has already incorporated AI and emerging technologies into its 2030 vision.[49;50] Yet, considering the rapid acceleration of digital transformation, even this forward-looking timeline may prove conservative in the face of technological momentum.

There are many examples that show the rapid development of technology. An example is the development of airplanes from the early wooden ones more than 100 years ago to today's jets. In the same way, forensic

[43] Information available at *https://innocenceproject.org/cases/kirk-bloodsworth/*, last consulted on 29.03.2025.

[44] Information available at *https://www.theguardian.com/uk/2009/mar/12/dna-kiszko-cardiff-three-stagg?utm_source=chatgpt.com,* last consulted on 29.03.2025.

[45] Information available at *https://innocenceproject.org/cases/frank-sterling/*, last consulted on 29.03.2025.

[46] Information available at *https://innocenceproject.org/cases/steven-avery/*, last consulted on 29.03.2025.

[47] Information available at *https://www.nytimes.com/2018/04/27/health/dna-privacy-golden-state-killer-genealogy.html*, last consulted on 29.03.2025.

[48] Information available at *https://innocenceproject.org/tags/central-park-five/*, last consulted on 29.03.2025.

[49] ENFSI, *Vision of the European Forensic Science Area 2030: Improving the Reliability and Validity of Forensic Science and Fostering the Implementation of Emerging Technologies*, European Network of Forensic Science Institutes ENFSI, 2022.

[50] Information available at *https://en.wikipedia.org/wiki/European_Network_of_Forensic_Science_Institutes#:~:text=The%20European%20Network%20of%20Forensic,cooperation%20with%20European%20police%20forces*, last consulted on 29.03.2025.

science has undergone development and new analysis methods continue to pave the way for making the most of physical and digital traces from crimes.[51]

There exists a wide array of artificial intelligence methods, with new approaches continually emerging. Yet, despite these advances, current AI systems have not reached the depth and nuance of the human mind. For now, AI largely replicates the swift, automatic functions of thought, lacking the conscious adaptability that defines human cognition. Autonomous systems, such as those used in vehicle navigation, struggle to respond to truly unforeseen events, whereas the human brain can swiftly summon deliberate, adaptive reasoning in novel situations. At the same time, AI surpasses human capacity when it comes to storing and processing vast volumes of heterogeneous data, rendering it particularly valuable in domains such as linguistic and visual recognition.[52;53]

This complementarity between human and machine calls for a redefinition of their collaboration. Artificial intelligence holds the potential to become an indispensable ally in navigating the intricate labyrinth of today's cyber investigations, such as analyzing billions of IP addresses in the pursuit of online criminal activity. Yet, the ultimate responsibility remains firmly in the hands of the forensic expert, whose judgment, ethical discernment, and contextual understanding continue to anchor the investigative process.[54]

In practice, traces are transposed into digital vectors of information, whether fingerprints, DnA, or other biometric markers, and processed through classification algorithms to enable identification. In supervised learning, systems are trained on labeled datasets to discern patterns and predict outcomes. In contrast, generative models, used in the creation of text, images, or code, operate by receiving outputs as input and generating new content inspired by them. Yet, generative systems can only echo what they have been taught. When insufficiently trained on a subject, the resulting information may be distorted or misaligned with reality. The emergence of specialized AI variants, customized „ChatGPTs", opens new avenues, both constructive and illicit. One particularly troubling example is „WormGPT," a tool designed to aid criminal endeavors. These developments raise urgent questions about software reliability, especially regarding the error rates of code generated autonomously. The next evolutionary leap in AI points toward intelligent assistants, systems that blend generative models with voice interaction, digital twins, and immersive visualization technologies. Simultaneously, the widespread integration of AI introduces critical ethical dilemmas. Trust in the authenticity and security of these systems must be unwavering. While bias may influence both traditional and algorithmic methods, AI has the added vulnerability of inheriting and amplifying prejudices embedded within its training data. Therefore, rigorous training, continuous monitoring, and demographic-sensitive validation are not just recommended, but essential. For forensic science to remain a pillar of justice, the tools it embraces must be held to the highest standards of fairness, transparency, and human oversight.[55]

The integration of artificial intelligence into the realm of criminal justice has ushered in novel perspectives on the investigation and resolution of legal cases. Yet, concrete examples of reopened or revised proceedings based solely on evidence processed through AI remain, for now, scarce. Nevertheless, a growing body of research and pilot initiatives highlights the transformative potential of AI in this domain, particularly in parsing vast datasets and digital evidence, as is often required in cybercrime investigations. In such instances, AI facilitates the detection and tracking of illicit activities across the digital landscape, offering investigators unprecedented analytical depth.[56]

In this evolving context, the European Parliament's Resolution of 6 October 2021 concerning artificial intelligence in criminal law and its use by law enforcement and judicial authorities underscores the imperative of safeguarding fundamental rights and upholding the rule of law. The document stresses that the deployment of AI in criminal proceedings must be governed by principles of transparency, fairness, and accountability. It warns against the risks posed by automated decision-making systems that may lead to discrimination or the erosion of human dignity.

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[51] L. Klasén, N. Fock, R. Forchheimer, *The invisible evidence: Digital forensics as key to solving crimes in the digital age*, Forensic Science International, vol. 362, September 2024.

[52] M. Roser, *The brief history of artificial intelligence: the world has changed fast – what might be next?*, Our World in Data, 2022, available at *https://ourworldindata.org/brief-history-of-ai*, last consulted on 29.03.2025.

[53] L. Klasén, N. Fock, R. Forchheimer, *op. cit.*

[54] *Ibidem*.

[55] *Ibidem*.

[56] Information available at *https://www.europarl.europa.eu/topics/ro/article/20200918STO87404/inteligenta-artificiala-oportunitati-si-pericole*, last consulted on 29.03.2025.

Furthermore, the Resolution advocates for the preservation of meaningful human oversight in all AI-assisted judicial processes and calls for the establishment of robust supervisory and accountability mechanisms. Above all, it urges the creation of a clear legal framework at the European level to regulate the use of AI in criminal justice, thereby ensuring that emerging technologies serve justice in harmony with the values and legal standards of the EU.[57]

2.3. Digital Forensics

Digital forensics is a field at the intersection of technology and justice, designed to detect, preserve, analyze, and interpret electronic traces left in the virtual space.[58]

Digital forensics holds a threefold role: evidentiary, restorative, and preventive. Electronic evidence can become the cornerstone of prosecution or defense, carrying the same demonstrative power as physical evidence.[59]

Moreover, such traces may offer context, chronology, and motive, reconstructing, step by step, the narrative of a crime. For example, the analysis of Wi-Fi network traffic, deleted messages from messaging apps, or authentication logs can confirm or refute a person's presence at a given location and time.[60]

A fundamental aspect is the re-evaluation of electronic evidence in light of new technologies. Archived cases, once deemed unsolvable, can be reopened thanks to technical advances that now allow the extraction and analysis of digital traces previously inaccessible.[61] Thus, a demagnetized hard drive, an encrypted file, or a deleted email account can become objects of investigation once again, using advanced recovery techniques.[62]

Digital forensics requires an interdisciplinary approach - a common language among legal professionals, IT specialists, and forensic experts.[63] The interpretation of electronic evidence demands particular *finesse*, as data fragments can be volatile, easily manipulated, and prone to loss or compromise. Therefore, the digital chain of custody must observe strict standards: each access, each conversion, each analysis must be documented and verifiable.[64]

Furthermore, the re-evaluation of electronic evidence implies not only a technical reopening of cases but also an ethical and legal review of how such evidence was collected, stored, and used. Recent jurisprudence increasingly acknowledges the impact that digital surveillance methods may have on fundamental rights such as privacy and freedom of expression.[65]

In this context, the reassessment of electronic evidence becomes not only possible but necessary. It is not merely about reopening old files, it is about reaffirming a justice system that is unafraid to look again, through the lens of technology, at what once seemed sealed. Where once silence stood as the only verdict, today the data returns, speaking a new language, demanding both accountability and reparation.[66]

2.3.1. Case studies

A striking example of how modern forensics, including the analysis of digital evidence, can help correct judicial errors is the case of Amanda Knox, an American student who was convicted in Italy, alongside her former boyfriend Raffaele Sollecito, for the 2007 murder of her roommate Meredith Kercher. The detailed analysis of phone calls, text messages, and internet activity helped reveal inconsistencies in the prosecution's case, ultimately leading to her acquittal in 2015.[67]

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[57] Information available at *https://www.europarl.europa.eu/doceo/document/TA-9-2021-0405_RO.html*, last consulted on 29.03.2025.

[58] E. Casey, *Digital Evidence and Computer Crime*, Academic Press, 2011.

[59] M.K. Rogers *et al.*, *Computer Forensics Field Triage Process Model, Digital Investigation*, Elsevier, 2006.

[60] B. Nelson *et al.*, *Guide to Computer Forensics and Investigations*, Cengage Learning, 2020.

[61] B. Carrier, *File System Forensic Analysis*, Addison-Wesley, 2005.

[62] J. Sammons, *The Basics of Digital Forensics*, Syngress, 2014.

[63] M. Reith *et al.*, *An Examination of Digital Forensic Models*, International Journal of Digital Evidence, 2002.

[64] E. Kenneally, B. Brown, *Law and Policy of Computer Forensics: Investigating Cybercrime*, American Bar Association, 2006.

[65] European Union Agency for Fundamental Rights, *Surveillance by intelligence services: Fundamental rights safeguards and remedies in the EU*, Publications Office of the EU, 2017.

[66] C. Roux *et al.*, *The Sydney Declaration: Principles for Forensic Science and Practice*, Forensic Science International: Synergy, Elsevier, 2022.

[67] R.K. Sherwin, *The Digital Trial, Project Syndicate*, 12 Oct 2011, information available at *https://www.project-syndicate.org/commentary/the-digital-trial*, last consulted on 29.03.2025.

Michael Morton, convicted in Texas in 1987 for the murder of his wife Christine Morton, spent nearly 25 years in prison before being exonerated in 2011. Initially, the prosecution's case relied on misinterpretations of his behavior and the absence of a solid alibi. With the help of *The Innocence Project*, the case was reopened, and a re-evaluation of the evidence, including digital materials such as personal journals and police reports, revealed that key information had been withheld from the defense.[68]

In the case of George Zimmerman, accused of killing teenager Trayvon Martin in 2012, the analysis of audio recordings proved pivotal. Experts used digital analysis techniques to try to determine the identity of the person crying for help in 911 call recordings. Although the conclusions were contested and did not result in a conviction, the case highlighted the role that digital forensics can play in criminal proceedings.[69]

These examples illustrate how digital forensics can influence legal processes – whether by exonerating the wrongfully convicted or by providing additional evidence to support or challenge existing accusations. It is essential to underscore that the use of digital evidence requires a rigorous approach and strict adherence to legal procedures to ensure its integrity and reliability in court.

2.4. Other methods

In the intricate landscape of modern forensic science, numerous emerging techniques enrich the investigative palette, offering new horizons for the elucidation of criminal acts. Among these, 3D photogrammetry stands out as a method that allows for the three-dimensional reconstruction of crime scenes, facilitating detailed analyses of complex environments and preserving their integrity for subsequent examinations.[70]

Micro X-ray fluorescence spectrometry represents another significant innovation, enabling the chemical composition analysis of microscopic particles on surfaces such as clothing or skin, thus revealing traces of contact and the environments frequented by the suspect.[71]

In the realm of identification, automated facial recognition and fingerprint matching systems have revolutionized the process of comparing individual features with existing databases, greatly accelerating suspect identification and minimizing human error.

The stable isotope analysis of water provides investigators with the ability to determine a person's geographic origin or travel path by examining the unique isotopic signatures of water absorbed by the body – signatures that vary depending on geographical location.[72]

Advanced imaging techniques, such as *virtopsy*, are increasingly used to replace or complement traditional autopsies through the application of scanning technologies, offering a non-invasive alternative for the detailed examination of bodies and the determination of cause of death.[73]

Facial reconstruction is employed to recreate an individual's appearance based on skeletal structures, proving essential in cases where conventional identification methods are unavailable.[74]

Virtual reality and deep learning technologies are being integrated into crime scene investigations, allowing for immersive re-creations and explorations of the scenes, as well as the automated recognition of objects of forensic interest – enhancing both the analysis and the preservation of evidence.[75]

These methods, alongside the classical tools of the forensic discipline, constitute a sophisticated arsenal in service of justice, each contributing to the unraveling of criminal enigmas and the reestablishment of truth within the complex theatre of forensic investigation.

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[68] Information available at *https://www.google.com/search?client=safari&rls=en&q=Michael+Morton+the+innocence+project&ie=UTF-8&oe=UTF-8*, last consulted on 29.03.2025.

[69] Information available at *https://en.wikipedia.org/wiki/Killing_of_Trayvon_Martin*, last consulted on 29.03.2025.

[70] Z. Ujvari, M. Metzger, G. Gardonyi, *A consistent methodology for forensic photogrammetry scanning of human remains using a single handheld DSLR camera*, National library of medicine, 28.09.2023, available at htt*ps://pmc.ncbi.nlm.nih.gov/articles/PMC10894066/*, last consulted on 29.03.2025.

[71] YRKM Sai, Advancing forensic science: *Addressing challenges and embracing emerging technologies*, Forensic Science Today, 30 December, 2022, available at *https://www.biolscigroup.us/articles/FST-8-123.php*, last consulted on 29.03.2025.

[72] *Ibidem*.

[73] Information available at *https://en.wikipedia.org/wiki/Virtopsy*, last consulted on 29.03.2025.

[74] Information available at *https://lifs.co.in/blog/forensic-science-techniques.html*, last consulted on 30.03.2025.

[75] A. Zappala, L. Guernera, V. Rinaldi, S. Livantino, S. Battiato, *Enhancing Crime Scene Investigations through Virtual Reality and Deep Learning Techniques*, 27 September 2024, available at *https://doi.org/10.48550/arXiv.2409.18458*, last consulted on 29.03.2025.

3. Legal and operational considerations

As criminal justice increasingly intersects with technological innovation, the issue of standardization and admissibility of evidence derived from emerging forensic technologies has become a central topic of legal and scientific discourse.

Currently, at the international level, courts assess the admissibility of such evidence based on criteria such as methodological reliability, recognition within the scientific community, and adherence to the chain of custody. In USA, for instance, the applicability of new technologies is examined under the *Daubert standard*, which requires that the technique be testable, peer-reviewed, possess a known error rate, and enjoy scientific acceptance in the relevant community.[76]

In Europe, judicial systems more commonly adhere to the principle of free evaluation of evidence, provided that the defendant's right to a fair trial, the legality of evidence collection, and the adversarial principle are fully respected.[77]

As for standardization, organizations such as the European Network of Forensic Science Institutes (ENFSI) play a pivotal role in harmonizing methodologies. ENFSI has issued a series of Best Practice Manuals for disciplines including DnA analysis, toxicology, digital traces, and ballistics, establishing protocols for method validation and laboratory auditing.[78]

A concrete example is the use of Rapid DnA technology in the United States, where this method was approved by the FBI for use within the CODIS network (Combined DnA Index System – a national DnA database managed by the FBI in USA, which allows for the storage, comparison, and matching of DnA profiles for judicial purposes[79]) only after standard protocols for operation, validation, and quality control had been established.[80]

Nevertheless, courts remain cautious when faced with evidence derived from under-tested technologies. For instance, facial recognition and predictive policing based on machine learning continue to raise serious concerns due to algorithmic bias and the opacity of their decision-making processes.[81]

European courts have been particularly strict in excluding digital evidence obtained outside a lawful framework, especially in cases involving electronic surveillance without judicial warrant. ECtHR, in landmark rulings such as *Case Bărbulescu v. Romania* (2017), reaffirmed that the use of technology in criminal proceedings must not compromise the right to privacy or the fairness of trial proceedings.[82]

At the international level, there is a growing tendency toward harmonizing legal frameworks regarding the admissibility of technologically-derived evidence. The European Parliament's 2001 Resolution on combating cybercrime laid the first legal groundwork for the use of electronic evidence while protecting fundamental rights in the digital sphere.[83]

This initiative was reinforced by the 2021 European Parliament Resolution on Artificial Intelligence in Criminal Law, which calls on Member States to ensure transparency, human oversight, and accountability in deploying AI and digital tools in judicial proceedings.[84]

Thus, while national systems preserve a degree of autonomy in their evidentiary assessments, a convergence toward shared principles is becoming increasingly visible: legality, relevance, scientific validity, and the procedural rights of the accused are gradually forming the pillars of an international standard for mutual recognition and compatibility of digital and scientific evidence.

Beyond their use in ongoing trials, emerging forensic technologies play an ever more vital role in the review and reopening of already adjudicated cases. Several jurisdictions have implemented mechanisms for post-conviction review, particularly when technological advances, such as modern DnA testing, digital forensics, or advanced data analytics, reveal information previously unattainable.

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

[77] K. Lenaerts, I. Maselis, K. Gutman, *EU Procedural Law*, Oxford University Press, 2014.

[78] ENFSI, *Best Practice Manuals* Series, 2021, information available at *https://enfsi.eu*, last consulted on 30.03.2025.

[79] Information available at *https://en.wikipedia.org/wiki/Combined_DNA_Index_System*, last consulted on 30.03.2025.

[80] FBI, *Standards for Rapid DnA Analysis*, 2020, available at *www.fbi.gov*, last consulted on 30.03.2025.

[81] Joh, E.E., *Artificial Intelligence and Policing: First Questions*, Seattle University Law Review, 2019.

[82] ECtHR, *Case Bărbulescu v. România* (61496/08), 05.09.2017, available at *https://hudoc.echr.coe.int/eng#{%22itemid%22:[%22001-177333%22]}*, last consulted on 30.03.2025.

[83] Resolution from 03.10. 2017 (2017/2068(INI)).

[84] Resolution from 06.10.2021 (2020/2016(INI)).

Programs such as *The Innocence Project* in USA or the *Criminal Cases Review Commission* (CCRC) in UK have led to the reassessment of hundreds of cases, often resulting in the exoneration of individuals wrongfully convicted based on outdated or insufficient forensic evidence.

In this light, the review of criminal trials is no longer a mere procedural afterthought but a restorative act of justice, through which the truth, long buried, may resurface, and judicial errors be acknowledged and corrected.

Though emerging technologies offer immense evidentiary potential, their integration into the justice system remains contingent upon an evolving normative framework, rigorous scientific validation, and jurisprudence that balances innovation with fundamental rights. Only through clear and unified regulation at the international level can these instruments become fully integrated into criminal proceedings without compromising the principles of legality, fairness, and legitimacy.

4. Conclusions. *De lege ferenda*

In an era where scientific progress transcends the boundaries once imagined by legal thought, criminal justice finds itself compelled to reconfigure its instruments and paradigms in order to meet the increasingly intricate complexity of evidentiary truth. Beyond mere efficiency or speed, emerging technologies, whether we speak of next-generation DnA analysis, digital forensics, computational intelligence, or three-dimensional reconstructions of crime scenes, carry a deeper promise: the restoration of truth, wherever it has been ignored, distorted, or lost.

These technological advancements must not be seen as mere operational conveniences, but rather as pillars of a restorative justice, one in which the reexamination of cold cases becomes not only a legal necessity, but a moral obligation. Cases such as those of Kirk Bloodsworth, Stefan Kiszko, Frank Sterling, or Amanda Knox remind us that miscarriages of justice are not relics of a bygone era, but persistent realities that can be righted when science is allowed to speak.

The standardization, validation, and unified regulation of these technologies, both with respect to their admissibility in court and their role in post-conviction review, are essential safeguards, ensuring that progress does not drift into arbitrariness. In this regard, frameworks like the *Daubert standard* in the United States or the best practices promoted by the European Network of Forensic Science Institutes (ENFSI) in Europe draw the contours of a system where scientific rigor must walk hand in hand with the protection of fundamental rights.

Above all, the reevaluation of criminal cases through the lens of emerging forensic tools is not a weakness of the justice system, but rather a testament to its strength, the strength to confront its past, to learn from its errors, and to restore dignity to those from whom it was unjustly taken. In a world where data speaks and digital traces can no longer be easily erased, justice is called not only to judge, but to listen anew, with new instruments, to the silence that has for decades obscured the truth.

Thus, technology is not merely a mirror of scientific progress, but a window into a future where truth may not only be told, but demonstrably proven. And where words have failed, science at last may be granted the final say - in the name of justice.

For criminal justice to integrate emerging forensic technologies in a legitimate and effective manner, a profound adaptation of the legal framework is necessary, both at the national and international levels. Scientific advances cannot be allowed to operate within a normative vacuum, and the re-evaluation of cases already adjudicated must be grounded in clear rules that balance legal certainty with the right to redress judicial error.

De lege ferenda

A. Establishment of a specific legal framework for retrial based on new scientific evidence. A legal provision is required to expressly regulate the possibility of revising final criminal judgments when new types of evidence become available - evidence obtained through technologies that were not accessible or recognized at the time of trial. This ground for retrial should explicitly include methods such as next-generation DnA sequencing (NGS), advanced digital forensics, computational analysis of evidence, or three-dimensional reconstructions of crime scenes.

B. Creation of specialized post-conviction review commissions. Inspired by the British model (Criminal Cases Review Commission) or initiatives like *The Innocence Project* in USA, an independent body could be established with exclusive authority to examine petitions for retrial based on new technological evidence. This

commission should include jurists, forensic scientists, and experts in science and ethics, ensuring a multidisciplinary approach to justice.

C. Mandatory long-term preservation and archiving of physical and digital evidence. Given that many cases remain unsolved or are concluded without adequate technological means at the time of investigation, the law should require the long-term retention of material evidence (biological traces, physical objects, digital files), so they may be reexamined as science advances.

D. Standardization of admissibility criteria for evidence obtained through emerging technologies. A harmonized legal framework should be established to govern the admissibility in court of evidence derived from modern scientific methods, with strict adherence to criteria such as reliability, verifiability, and scientific recognition. Useful references would include the *Daubert standard* (USA) or the best practice manuals issued by ENFSI (EU) concerning forensic methodology validation.

E. Introduction of a national registry for judicial errors overturned by scientific evidence. To increase transparency and trust in the justice system, a public registry documenting all cases revised due to emerging technological evidence should be created. This database could also serve as a foundation for statistical, educational, and normative analyses of the vulnerabilities in the criminal justice process.

F. Mandatory legal-scientific education for judges and attorneys. Given the complexity and specificity of evidence obtained through advanced technologies, continuous training for judges and attorneys in modern forensic science is imperative. It is recommended that such modules be included in both initial and ongoing legal education, as well as through institutional collaboration with forensic research centers.

G. Clarification of the legal status of algorithms and automated tools used in criminal investigations. In light of the increasing use of computational intelligence in evidence analysis and predictive modeling (*e.g.*, predictive policing, facial recognition), explicit regulation is necessary concerning the transparency, auditability, and contestability of decisions generated by automated systems.

These proposals aim not merely at the technical adjustment of the legal system, but at reinforcing its fundamental purpose: to serve the truth and to mend what justice, in its fallibility, has once fractured. Technology is not a tribunal but it may become a bridge between what was lost and what might still be restored. And the law, in its solemn silence, must be prepared to listen.

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