THE APPLICATION OF DNA IDENTIFICATION TECHNIQUES IN THE CRIMINAL JUSTICE FIELD

Li Tingting

Universiti Kebangsaan Malaysia (UKM), Bangi, Malaysia

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ABSTRACT

DNA is the unique scientific, accurate and exclusive nature of DNA as an inherent "identity card" for everyone. DNA identification techniques make use of these characteristics of DNA to match the biological traces left at the crime scene by the perpetrator of the crime with the data in the DNA database, using scientific and technological analysis methods. This is used to prove its relevance to an investigation. However, DNA evidence is not infallible and has its "Achilles' Heel". Based on this situation, this article examines the development of DNA identification technology, the factors that affect the accuracy of its findings, and the value of its application in the field of criminal justice, through interviews, literature research, case studies, generalizations and empirical research. In the study, certain recommendations are given on technical standards, the development of sound laws and regulations, and the enrichment of DNA databases. Some practical improvement strategies are proposed for the increasing improvement of DNA identification technology in China and its greater function in the detection of cases by public security authorities.

Keywords: DNA Identification Techniques, Criminal Justice, Accuracy & Reliability

1. INTRODUCTION

DNA is a genetic material that is important for the survival and reproduction of living organisms, and

one of the most important factors in their survival and reproduction is the genetic material, DNA, which is rich in genetic characteristics and is a good tool for distinguishing and identifying individuals.[1] DNA identification is based on the information in an individual's DNA that remains largely unchanged throughout its life and is based on the sequence of bases in an individual's DNA, which is more difficult to falsify or alter than features such as physical appearance, and footprints or fingerprints, and is extremely stable.[2]

The advent and development of DNA identification techniques have had a disruptive impact on the way of individual identification.[3] The DNA fingerprinting technique invented by British geneticist Alec Jeffreys was the first generation of DNA analysis, also known as the Restriction Fragment Length Polymorphism (RFLP) technique and was first used in 1985 in an immigration case at the UK Home Office.[4] During the same year, Kary Mullis of PE-Cetus invented the polymerase chain reaction (PCR), which led to the rapid development of DNA analysis techniques.[5] In 1989, DNA fingerprinting was used for the first time in China to test actual cases. Since then, DNA identification techniques have played an increasingly prominent role in the detection of cases in China. As DNA testing technology continues to develop and investigators become more aware of the need to collect evidence, DNA identification techniques have become more widely used and play an important role in the criminal field.[6] Its use has not only led to the successful detection of many serious and difficult cases but has also provided an opportunity for the reversal of many miscarriages of justice.[7]

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[1] Panneerchelvam, Sundararajulu, and Norazmi Mohd Nor. 2023. "DNA Profiling in Human Identification: From Past to Present." *Malaysian Journal of Medical Sciences* 30 (6): 5–21. https://doi.org/10.21315/mjms2023.30.6.2.

[2] Fei, Jiaer. 2022. "Innovation Research on Fingerprint and DNA Identifications." *Proceedings of Business and Economic Studies* 5 (2): 57–65. https://doi.org/10.26689/pbes.v5i2.3880.

[3] Wang, Jinliang. 2016. "Individual Identification from Genetic Marker Data: Developments and Accuracy Comparisons of Methods." *Molecular Ecology Resources* 16 (1): 163–75. https://doi.org/10.1111/1755-0998.12452.

[4] Bivins, Roberta. 2023. "Pilot Programs and Postcolonial Pivots: Pioneering 'DNA Fingerprinting' on Britain's Borders." *Comparative Studies in Society and History* 65 (2): 346–71. https://doi.org/10.1017/S0010417522000494.

[5] Zhang, Haoqing, Huanan Li, Hanliang Zhu, Jan Pekárek, Pavel Podešva, Honglong Chang, and Pavel Neužil. 2019. "Revealing the Secrets of PCR." *Sensors and Actuators B: Chemical* 298 (November): 126924. https://doi.org/10.1016/j.snb.2019.126924.

[6] Bivins, Roberta. 2023. "Pilot Programs and Postcolonial Pivots: Pioneering 'DNA Fingerprinting' on Britain's Borders." *Comparative Studies in Society and History* 65 (2): 346–71. https://doi.org/10.1017/S0010417522000494.

[7] Wemegah, Joshua. 2022. "Forensic Detection through the Identification and Collection of Data for Analysis." *Advances in Multidisciplinary and Scientific Research Journal Publication* 1 (1): 1–6. https://doi.org/10.22624/AIMS/CRP-BK3-P1.

Under the aura of "indisputable science", people have become extremely convinced of DNA evidence, and its unique probative function has been so effective that it has earned the reputation of being the "king of the new generation of evidence". However, in practice, the improper use of DNA evidence has led to several unjustified cases, and people have come to realise that it has its flaws, apart from the inherent flaws of DNA, a series of procedural problems involving DNA identification, such as irregularities in the procedures of extraction, collection, storage, transfer and identification, differences in identification methods and professionalism of laboratory personnel, and inconsistencies in DNA data databases.[8] This has led to a series of problems in the use of DNA evidence in practice. In this regard, this paper aims to discuss the basic concepts and biological basis of DNA evidence and to analyse and discuss how to improve the accuracy and reliability of DNA identification conclusions in the context of the use of DNA evidence in Chinese criminal justice practice, and on this basis, to put forward relatively feasible suggestions for improvement.

2. RESULT AND DISCUSSION

2.1 DEFINITION OF DNA PROPERTIES AND DNA IDENTIFICATION TECHNIQUES

2.1.1Definition of DNA Properties

The human individual originates from a single fertilized egg cell, which derives half of its information code from its male parent and a half from its female parent.[9] The fertilized egg cell continues to replicate and divide, gradually forming a variety of different tissues, organs and systems, culminating in a human being with approximately 100 trillion cells.[10] Each of the 100 trillion or so cells in a human being is replicated from a fertilized egg and therefore each cell contains the same genetic information as the fertilized egg. Human genetic information consists of 22 pairs of

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[8] Mortera, Julia. 2020. “DNA Mixtures in Forensic Investigations: The Statistical State of the Art.” *Annual Review of Statistics and Its Application* 7 (1): 111–42. https://doi.org/10.1146/annurev-statistics-031219-041306.

[9] Vissing, John. 2019. “Paternal Comeback in Mitochondrial DNA Inheritance.” *Proceedings of the National Academy of Sciences* 116 (5): 1475–76. https://doi.org/10.1073/pnas.1821192116.

[10] Nugues, Charlotte, Nordine Helassa, and Lee P. Haynes. 2022. “Mitosis, Focus on Calcium.” *Frontiers in Physiology* 13 (June). https://doi.org/10.3389/fphys.2022.951979.

autosomes and one pair of sex chromosomes, making up a total of 23 pairs of 46 chromosomes, each pair coming from one of the parents.[11] On each chromosome are stored more than 100,000 pairs of genes, the most basic units of inheritance. It is these genes that determine all the genetic traits a person has, both those common to humans and those that are unique to the individual. Genes are made up of DNA. DNA is the abbreviation of the English word deoxyribonucleic acid-binding oncoprotein, a long, repeating chain of four nucleotides.[12] Each nucleotide consists of a phosphate, a deoxyribonucleic acid and a different base, and there are four bases in DNA: Adenine, Thymine, Cytosine and Guanine, which are represented by the abbreviations A, T, C and G respectively. In a DNA molecule, there are four possibilities for the bases in each nucleotide.[13]

2.1.2DNA Identification Techniques

The DNA identification process, in the criminal justice context, refers primarily to the DNA establishing identity process.[14] Firstly, biopsies (e.g., blood, saliva, hair, finger dander, etc.) are obtained from the suspect and then a purified DNA sample is obtained from the biopsies to create a 'known sample'. On the other hand, a DNA sample from the biopsy is collected from the crime scene to create an "evidence sample". "By comparing the "known sample" with the "evidence sample", it is possible to determine whether the two samples are from the same organism. Different organisms have different numbers, sizes and base sequences of DNA.[15] Organisms of the same species have the same number and size of DNA molecules, but the base sequence of the DNA varies greatly between individuals. This constitutes a specific basis for DNA identification. DNA identification techniques

[11] Heilig, Roland, Ralph Eckenberg, Jean-Louis Petit, Núria Fonknechten, Corinne da Silva, Laurence Cattolico, Michaël Levy, et al. 2003. "The DNA Sequence and Analysis of Human Chromosome 14." *Nature* 421 (6923): 601–7. https://doi.org/10.1038/nature01348.

[12] Smith, Eric A., Eric F. Krumpelbeck, Anil G. Jegga, Malte Prell, Marie M. Matrka, Ferdinand Kappes, Kenneth D. Greis, Abdullah M. Ali, Amom R. Meetei, and Susanne I. Wells. 2018. "The Nuclear DEK Interactome Supports Multi-functionality." *Proteins: Structure, Function, and Bioinformatics* 86 (1): 88–97. https://doi.org/10.1002/prot.25411.

[13] Nieuwland, Celine, Trevor A. Hamlin, Célia Fonseca Guerra, Giampaolo Barone, and F. Matthias Bickelhaupt. 2022. "B-DNA Structure and Stability: The Role of Nucleotide Composition and Order." *ChemistryOpen* 11 (2). https://doi.org/10.1002/open.202100231.

[14] Pope, Susan, and Roberto Puch-Solis. 2021. "Interpretation of DNA Data within the Context of UK Forensic Science — Investigation." *Emerging Topics in Life Sciences* 5 (3): 395–404. https://doi.org/10.1042/ETLS20210165.

[15] Zhou, Wanding, Gangning Liang, Peter L. Molloy, and Peter A. Jones. 2020. "DNA Methylation Enables Transposable Element-Driven Genome Expansion." *Proceedings of the National Academy of Sciences* 117 (32): 19359–66. https://doi.org/10.1073/pnas.1921719117.

are used to analyse DNA polymorphisms that are of specificity identification value, using probabilistic and statistical methods, to identify the same DNA for a particular group.

A philosopher once said that no two leaves in the world are the same. It is precise because things are different, and it is possible to identify them according to the differences in their characteristics. Modern genetics shows that "the vast majority of DNA molecules (more than 99.7%) are the same in different individuals, with only a small portion (less than 0.3%, i.e. about 10 million nucleotides) different, and these differences make us unique individuals, using this part of DNA polymorphic information to make individual human identification possible.[16] However, even for this 0.3% difference, it is still impossible to detect all the differences in DNA in forensic examinations due to the limited resources available.[17] Therefore, when we want to distinguish whether two samples (samples) are owned by the same person, we do not actually decode all 3 billion base pairs but select a very small number of specific polyphenic regions based on the polyphenism of DNA itself, analyse the polyphenic DNA fragments in that region, and then statistically establish the probability of the occurrence of DNA polyphenism in the population. The probability of DNA polyphenism in a population is then established statistically. The DNA polyphenisms are then linked to several independent, unlinked DNA polyphenism systems to form a gene pool sufficient to discriminate between specific groups.[18]

2.1.3THE GERMINATION AND DEVELOPMENT OF DNA IDENTIFICATION TECHNIQUES

The scientific community has been exploring DNA for hundreds of years. In 1868, the Austrian Gregor Mendel discovered the laws of heredity, laying the foundation for modern genetic science.[19]

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[16] Algee-Hewitt, Bridget F.B., Michael D. Edge, Jaehee Kim, Jun Z. Li, and Noah A. Rosenberg. 2016. "Individual Identifiability Predicts Population Identifiability in Forensic Microsatellite Markers." *Current Biology* 26 (7): 935–42. https://doi.org/10.1016/j.cub.2016.01.065.

[17] Haddrill, Penelope R. 2021. "Developments in Forensic DNA Analysis." *Emerging Topics in Life Sciences* 5 (3): 381–93. https://doi.org/10.1042/ETLS20200304.

[18] Toga, Kouhei, Kakeru Yokoi, and Hidemasa Bono. 2022. "Meta-Analysis of Transcriptomes in Insects Showing Density-Dependent Polyphenism." *Insects* 13 (10): 864. https://doi.org/10.3390/insects13100864.

[19] Gerashchenkov, G.A., D.A. Chemeris, Z.R. Vershinina, F.R. Gimalov, A.R. Sakhabutdinova, N.A. Rozhnova, E.V. Mikhailova, et al.

Then, in 1969, Miescher, a young Swiss student, discovered DNA in animal cells. In 1953 James Watson and Francis Click discovered the double helix structure of the DNA molecule. They used the characteristics of the DNA molecule itself to explain properties that included the ability to replicate itself stably and pass from one generation to the next. This marked the birth of modern molecular biology. These studies laid the foundation for DNA identification techniques.

2.1.3.1The Initial DNA Identification Technique ——DNA Fingerprint Technique（RFLP）

This technique involves obtaining a "DNA fingerprinting" consisting of 15-20 individual chromosomal bands from a small DNA molecule and was the first method used in scientific DNA testing in the courts.[20] In 1984 the British scientist Alec Jeffreys, investigating DNA genetic markers for disease, discovered that RFLP profiles, like human fingerprints, were unique and could be used for personal identification, thus breaking the history of" exclusion is certain, identification is relative" for personal identification.[21]

The earliest use of DNA fingerprinting in criminal justice was in 1986.[22] There was a major rape and murder of two British girls in the East of England, and the perpetrators in both cases were so similar that the police deduced that the two cases were likely to have been committed by one person, but the suspect, who had been arrested by the police, refused to admit that he had done both. The police then took samples from the murder scene and sent them to Alec Jeffreys for testing, which showed that the two murders were indeed committed by the same person, but not by the same suspect they had arrested. In 1986, the suspect was released based on DNA evidence. This was the first case in which DNA evidence was used to exclude an innocent suspect and the first case in which DNA evidence

2023. “The Genius of Gregor Mendel and the Genome of the First Geneticist.” *Biomics* 15 (2): 96–138. https://doi.org/10.31301/2221-6197.bmcs.2023-13.

[20] Mishra, Amarnath, and Sukumaran Sathyan. 2017. “Role of DNA Fingerprinting in Disputed Paternity.” *Med Phoenix* 1 (1): 44–46. https://doi.org/10.3126/medphoenix.v1i1.17889.

[21] Castro, Bruno Bello Pede, Solange Maria Gennari, Hernan Lorenzi, and Chunlei Su. 2020. “A Simple Method to Generate PCR-RFLP Typing Profiles from DNA Sequences in Toxoplasma Gondii.” *Infection, Genetics and Evolution* 85 (November): 104590. https://doi.org/10.1016/j.meegid.2020.104590.

[22] Verma, Sunil K., and Gajendra K. Goswami. 2014. “DNA Evidence: Current Perspective and Future Challenges in India.” *Forensic Science International* 241 (August): 183–89. https://doi.org/10.1016/j.forsciint.2014.05.016.

was used to identify the accused. It was also the first case in which DNA evidence was used to convict a defendant.[23]

However, the technique is difficult to obtain accurate and reliable analysis results for samples with severely degraded DNA or very few nuclei, and the amount of sample required is large, generally requiring 50-100ng, making it difficult to obtain such large and undegraded DNA samples at the scene of a criminal investigation; most importantly, because of factors such as deformation of the electrophoresis gel and drift of the spectral band, the accuracy of the test analysis results is not high and errors are large.[24]

2.1.3.2Revolutionary Advances - PCR Technology

The Polymerase Chain Reaction (PCR) technique was invented in 1985 by Mullis and Saiki et al. of Cetus, USA. This technique is a pre-procedure for DNA identification, i.e., the external amplification of specific sequences of DNA.[25] The PCR technique allows the identification of two types of DNA variants, Variable Number of Tandem Repeat (VNTR) and Short Tandem Repeat (STR).

However, PCR itself is only a pre-processing technique for DNA identification, not a method of identification. In other words, PCR only provides a copy of a specific sequence in the DNA sequence, and the resulting PCR product must be combined with other methods to reveal its polytypism.[26] The major advantages of PCR methods over RFLP tests are the minimal amount of DNA required for analysis, the rapidity of the DNA amplification technique and the usefulness of the DNA analysis of

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[23] Meintjes-Van der Walt, Lirieka, and Priviledge Dhliwayo. 2021. "DNA Evidence as the Basis for Conviction." *Potchefstroom Electronic Law Journal* 24 (June): 1–35. https://doi.org/10.17159/1727-3781/2021/v24i0a8537.

[24] Carrasco, Patricio, Carolina Inostroza, Meghan Didier, Marianela Godoy, Cydne L. Holt, Jonathan Tabak, and Andrew Loftus. 2020. "Optimizing DNA Recovery and Forensic Typing of Degraded Blood and Dental Remains Using a Specialized Extraction Method, Comprehensive QPCR Sample Characterization, and Massively Parallel Sequencing." *International Journal of Legal Medicine* 134 (1): 79–91. https://doi.org/10.1007/s00414-019-02124-y.

[25] Zhang, Haoqing, Huanan Li, Hanliang Zhu, Jan Pekárek, Pavel Podešva, Honglong Chang, and Pavel Neužil. 2019. "Revealing the Secrets of PCR." *Sensors and Actuators B: Chemical* 298 (November): 126924. https://doi.org/10.1016/j.snb.2019.126924.

[26] Zhang, Zengming, Shuhao Zhao, Lei Jiang, Junjun Wu, Wenhan Zhao, Xiaoniu Guo, Niancai Peng, and Fei Hu. 2022. "A Sample-to-Answer DNA Detection Microfluidic System Integrating Sample Pretreatment and Smartphone-Readable Gradient Plasmonic Photothermal Continuous-Flow PCR." *The Analyst* 147 (21): 4876–87. https://doi.org/10.1039/D2AN00908K.

degraded or partially decayed biological samples. Based on this, the PCR method is now the standard technique used in the majority of court science laboratories.

2.1.3.3Further Development of DNA Identification Techniques – Y-STR Technology

Y-STR tests the human sex chromosomes. There are 23 pairs of chromosomes in the human body, XX for females and XY for males, in which the Y chromosome is unique to males.[27] The Y-STR analysis technology is mainly used for family lineage search, which can first determine the family range of the suspect, and then carry out autosomal matching or other investigative methods to finally identify the individual suspect. The police can extract the Y chromosome from male members' hair with hair follicles, blood, oral mucosa, semen, nails and muscle tissue.

The application of DNA analysis of the Y chromosome began in the 1980s.[28] The first Y chromosome-specific probe for sex determination was synthesized by Lau et al. at the University of California in 1984, named pY3.4 because of the use of endonuclease to digest the 3.4 fragments of male genomic DNA, and in the same year, Y. Nakahori developed a pHY10 probe with the same sequence as pY3.4. In 1986 Tyler et al. first reported the application of the pY3.4 In 1988, Kobayashi et al. used a biotin-labelled pHY10 probe to determine the sex of human blood traces, and in the same year, Fukushima et al. reported the use of a Y chromosome-specific probe to examine male blood traces by speckle hybridization.[29]

The advantages of this analysis technique are even more outstanding in criminal cases. By interviewing the Chinese Criminal Investigation Team, I learned that males are more likely to

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[27] Balayan, Ajay Parkash, Vivek Kumar, Prateek Pandya, Uma Kanga, Tulika Seth, and Anupuma Raina. 2021. "Chimeric Status of Biological Samples after HSCT for Personal Identification: Y-STR Based DNA Analysis in Sex Mismatch Cases." *Forensic Science International* 318 (January): 110639. https://doi.org/10.1016/j.forsciint.2020.110639.

[28] Syndercombe Court, Denise. 2021. "The Y Chromosome and Its Use in Forensic DNA Analysis." *Emerging Topics in Life Sciences* 5 (3): 427–41. https://doi.org/10.1042/ETLS20200339.

[29] Fehse, Boris, Alexei Chukhlovin, Klaus Kühlcke, Olga Marinetz, Oliver Vorwig, Helmut Renges, William Krüger, et al. 2001. "Real-Time Quantitative Y Chromosome-Specific PCR (QYCS-PCR) for Monitoring Hematopoietic Chimerism after Sex-Mismatched Allogeneic Stem Cell Transplantation." *Journal of Hematotherapy & Stem Cell Research* 10 (3): 419–25. https://doi.org/10.1089/152581601750289028.

commit crimes through criminal activity. The interviewees said that males are more emotionally charged and commit crimes at a much higher rate overall than females. Then the method of DNA identification and analysis using the Y chromosome is more beneficial for criminal investigation, it can target the suspect's family line, which can be more effective for targeted investigation, and then with autosomal STR technology in this family line longitudinal search can effectively find the criminal person.[30] The interviewees also made a point of mentioning rape and gang rape cases, saying that using Y-chromosome-specific PCR primers can improve the detection rate of low levels of male offenders' DNA when the proportion of female victims' DNA is large and can help solve cases more effectively. However, the interviewee also stressed that we also need to be aware of its limitations, as the Y-STR analysis technique currently requires the assistance of other DNA identification analysis techniques to ultimately and accurately identify the perpetrator.

2.1.3.4The Development of Forensic DNA Identification techniques in China

Since the end of the 1980s, Chinese forensic DNA technology has gone through a process of gradual development and growth from scratch. In 1985, Chinese court scientists noticed the "DNA fingerprinting" technology pioneered by Jeffreys et al. and immediately followed this project technology and started to conduct "Forensic research on blood DNA fingerprinting". Forensic research on blood DNA fingerprinting". In 1987, China began to apply DNA fingerprinting techniques to identify cases. In 1989, the Second Research Institute of the Ministry of Public Security and the Liaoning Provincial Public Security Department took the lead in successfully applying this technology to the identification of rape cases, murder cases, child abduction cases and property disputes, solving many difficult cases.[31] Since then, China's forensic biological evidence testing technology has leapt from only being able to exclude to directly identifying.

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[30] Yang, Xingyi, Hong Liu, Changhui Liu, Quyi Xu, Dian Yang, XiaoLong Han, Ling Chen, Bo Lei, Chao Liu, and Weian Du. 2020. "Application of Y-Chromosomal Microdeletions in a Homicide Case." *Forensic Science International* 314 (September): 110370. https://doi.org/10.1016/j.forsciint.2020.110370.

[31] Liu, Yanlei, Chao Xu, Wenpan Dong, Xueying Yang, and Shiliang Zhou. 2021. "Determination of a Criminal Suspect Using Environmental Plant DNA Metabarcoding Technology." *Forensic Science International* 324 (July): 110828. https://doi.org/10.1016/j.forsciint.2021.110828.

In 1996, based on the Second Research Institute of the Ministry of Public Security, the Physical Evidence Identification Centre of the Ministry of Public Security was established. The DNA Identification Division under the Centre is responsible for the construction, management and related scientific research of the national DNA database, and as of October 2010, China's DNA database stored 6.5 million pieces of information, becoming the third-largest database in the world after the United States and the United Kingdom. The database is an important way to fully play the role of DNA technology, so that DNA technology from a single passive identification tool, into the active investigation, an important means of direct crime-solving, especially for the parallel investigation of the backlog of cases, timely and accurate detection of cross-regional crime to provide an efficient scientific means, in the casework highlights its important practical value and extremely broad prospects for development.[32]

2.1.4THE VALUE OF DNA IDENTIFICATION TECHNIQUES IN THE CRIMINAL JUSTICE FIELD

Nowadays, DNA identification technology is particularly used in criminal investigations, mostly in some major and difficult cases, especially murder cases and rape cases, mainly by comparing DNA with the DNA of the suspect by comparing the traces left behind by the perpetrator at the scene or by comparing the DNA of the victim's blood and other evidence, to clarify the relationship between the suspect and the crime scene, the suspect and the victim. thereby establishing the facts of the case. The main applications are described in the following three sections.

2.1.4.1Facilitate the Detection of Long-standing and Serious Cases

DNA identification techniques are often an important criminal technology tool for determining the identity of a person and based on DNA identification opinions it can be determined that the biological samples from the crime scene came from a certain person, thus proving his relevance to the case. In the investigation, the widespread use of DNA identification technology has made it

[32] Udogadi, Nwawuba Stanley, Mohammed Khadija Abdullahi, Adams Tajudeen Bukola, Omusi Precious Imose, and Ayevbuomwan Davidson Esewi. 2020. “Forensic DNA Profiling: Autosomal Short Tandem Repeat as a Prominent Marker in Crime Investigation.” *Malaysian Journal of Medical Sciences* 27 (4): 22–35. https://doi.org/10.21315/mjms2020.27.4.3.

possible to obtain accurate investigative clues and broaden the avenues of investigation. The speed of solving cases has been accelerated, resulting in the detection of a large number of difficult and complex and even some long-standing cases.

The first criminal case in China to use DNA evidence took place in Liaoning Province. At the time, a family in Kazuo County, Liaoning Province, lost a girl who was never found, and then a sheepherder found the girl's body in the mountains. When the forensic pathologist performed an autopsy on the body, he found that the girl was pregnant. The police then identified several suspects after an investigation. Still, they could not pinpoint the perpetrator according to previous blood tests, so they decided to conduct a DNA test, which eventually led to the identification of the real culprit.[33]

One of the most famous cases solved using DNA identification techniques is the "Baiyin City, Gansu Province serial murder case", in which 11 women were murdered in their homes in Baiyin City, Gansu Province, China, over 14 years from 1988 to 2002, some of the victims having been sexually assaulted, including an 8-year-old girl. Some of the victims were sexually assaulted, including an eight-year-old girl. The murders were brutal and highly concealed, causing great social fear. The investigators collected the fingerprints and DNA of the perpetrators at the scene of the crime, and the Baiyin Public Security Bureau then compared at least 100,000 fingerprints to catch the killer, but at that time, due to outdated technology, the case was slow to make substantial progress. As a result, the Baiyin police began to build the Y-STR database, which became the key to solving the case. The DNA of one of Gao Chengyong's cousins was entered into the database as a bribe, and the police compared it with the traces left at the scene of the murder and found a high degree of consistency between the sample and the sample taken at the scene of the "Baiyin Case" with 27 loci, and eventually found the real culprit to a member of the Gao family, Gao Chengyong. Twenty-eight years later, with the help of DNA technology, the Baiyin serial murder case, known as one of the ten most unsolved cases since the founding of the country, was finally solved on August 26, 2016, with the

[33] Haddrill, Penelope R. 2021. “Developments in Forensic DNA Analysis.” *Emerging Topics in Life Sciences* 5 (3): 381–93. https://doi.org/10.1042/ETLS20200304.

murderous maniac finally caught.[34]

2.1.4.2Facilitate the Clearing of Miscarriages of Justice

DNA identification techniques can lead to the timely clearing of innocent suspects from suspect status. By matching the results of typing tests on a suspect's DNA with the DNA of human remains from the crime scene, if a match cannot be made, the suspect can essentially be considered for exclusion. On the other hand, as DNA databases continue to grow in size, some people who have been convicted of crimes have been vindicated through DNA identification techniques. Statistics from the Federal Bureau of Investigation (FBI) show that approximately 1/3 of suspects are cleared by DNA testing and that other methods (e.g., blood typing, etc.) are not sufficient to clear suspects before DNA testing is used.[35]

In 1992, the Innocence Project was established in the United States, using advanced DNA science to vindicate innocent people. A search of the project's official website clearly shows that since its inception in 2001, it has successfully defended 204 cases, of which 193 cases have been acquitted by DNA evidence.[36] In other words, in 94.6% of cases, the judge quashed the conviction of the person serving the sentence based on DNA evidence. This percentage is a good indication of the value and usefulness of DNA identification techniques in detecting and correcting wrongful convictions. Meanwhile, in 2004, the US began implementing the five-year, $1 billion President's DNA Initiative, which aims to maximise the use of DNA technology to fight crime and protect the innocent.

In Chinese judicial practice, the vindication of wrongful convictions is not an easy task, so the above-mentioned role of DNA has not been obvious. But in the case of the sensational "Li

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[34] RIANTI, PUJI, ELISA CRISTIN, and PUTUT TJAHJO WIDODO. 2020. “Profil DNA Forensik Pada Barang Bukti Dua Kasus Pembunuhan Di Indonesia.” *Jurnal Sumberdaya Hayati* 4 (2): 48–56. https://doi.org/10.29244/jsdh.4.2.48-56.

[35] Amankwaa, Aaron Opoku, and Carole McCartney. 2021. “The Effectiveness of the Current Use of Forensic <scp>DNA</Scp> in Criminal Investigations in England and Wales.” *WIREs Forensic Science* 3 (6). https://doi.org/10.1002/wfs2.1414.

[36] Calacal, Gayvelline C., Frederick C. Delfin, and Maria Corazon A. de Ungria. 2022. “A Retrospective Look on the Use of DNA Evidence in a Sexual Assault Investigation in the Philippines.” *Acta Medica Philippina* 56 (15). https://doi.org/10.47895/amp.v56i15.3046.

Fengchun's alleged rape" in Shanxi, he was indeed spared jail time because of DNA identification techniques. On the night of April 3rd, 2000, two female secondary school students living in Datong, Shanxi Province, were brutally raped in their dormitory. The police investigated the case and concluded that Li Fengchun was a major suspect. The main evidence was, firstly, that Li Fengchun was a private teacher at the school and was familiar with the school and its surroundings; secondly, that he had been in the vicinity of the two girls' dormitory on the day of the crime; and, most importantly, that Li Fengchun's blood type was the same as that of the sperm substance left on the bedsheets of the two female students. After his criminal arrest, Li Fengchun pleaded not guilty to all charges. At the trial, Li Fengchun and his defence lawyers insisted that the sperm spots on the sheets be sent to the Chinese Ministry of Public Security's Physical Evidence Identification Centre for DNA identification, which concluded that the two sperm spots on the sheets were not left by Li Fengchun, who eventually relied on DNA identification technology to clear his name after 341 days of wrongful detention.

2.1.4.3Simulation of Imaging for Rapid Targeting of Suspects

DNA technology for phenotypic characterisation is mainly based on third-generation genetic markers - single nucleotide polymorphisms (SNPs).[37] A person's body shape, head shape and face shape are all determined by DNA genes. Since this is the case, court scientists can carry out DNA typing based on the hair, blood and saliva left at the crime scene to copy the suspect's portrait, thus providing reliable clues and key evidence to identify the case. To analyse the structure of facial features more comprehensively and finely, Tang Kun's research team at the Institute of Computational Biology, Shanghai Institutes for Biological Sciences, Chinese Academy of Sciences, has established a new fully automated non-rigid registration (non-rigid registration) 3D facial image mapping method using more refined facial 3D scan data, reaching 30,000 data points per face.[38]

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[37] Ding, Sheng, Rong Chen, Gangyi Chen, Mei Li, Jiayu Wang, Jiawei Zou, Feng Du, et al. 2019. "One-Step Colorimetric Genotyping of Single Nucleotide Polymorphism Using Probe-Enhanced Loop-Mediated Isothermal Amplification (PE-LAMP)." *Theranostics* 9 (13): 3723–31. https://doi.org/10.7150/thno.33980.

[38] Wen, Aonan, Yujia Zhu, Ning Xiao, Zixiang Gao, Yun Zhang, Yong Wang, Shengjin Wang, and Yijiao Zhao. 2023. "Comparison Study of Extraction Accuracy of 3D Facial Anatomical Landmarks Based on Non-Rigid Registration of Face Template." *Diagnostics* 13 (6): 1086. https://doi.org/10.3390/diagnostics13061086.

According to the forensic examiners interviewed, the application of DNA identification techniques in facsimile imaging is still in the exploration, research and development stage. The technology is not currently accurate enough to be used as evidence, but can only provide a general direction, and is still far from being truly and widely used in the investigation of criminal cases. However, we are working hard to improve its accuracy and reliability for early application in actual cases.

2.1.5THE ELEMENTS OF THE ACCURACY AND RELIABILITY OF THE FINDINGS OF DNA ANALYSIS

The DAN technique is not reliable and can be influenced by several factors that can ultimately lead to less accurate and less reliable results. As DNA requires a complex process to conclude, any error in the process can affect the authenticity and reliability of the identification.

2.1.5.1The Effect of The Sample Extraction Process on The Accuracy of Analysis Findings

Different extraction methods should be used for the extraction of DNA specimens from different sites. For items with soft, rough surfaces, easily permeable or with a large body contact surface, such as shirts, gloves, masks, etc., the negative pressure adsorption method is more effective in collecting examination material, with a success rate of 68.8% or more on average, which is better than other methods. And hard, smooth surface, not easy to penetrate or contact with the body surface of smaller items, the use of adhesive paper sticky or two-step wipe method success rate of 45% or more on average. However, knife handles, crowbars and bundles are collected less effectively, which may be related to the small area of contact between the sample and the body, the uncertainty of the contact area, the short contact time with the body and the fact that the offender may be wearing gloves to commit the crime. Older items left at the scene may be mixed with more contaminants at the same time, and it is best to use a method of DNA extraction using magnetic beads combined with a Kingfisher workstation that has a high extraction rate and good purification.[39]

[39] Topol, Aaron. 2021. "High Throughput RNA Extraction and PCR Inhibitor Removal of Settled Solids for Wastewater Surveillance of SARS-CoV-2 RNA V2." https://doi.org/10.17504/protocols.io.b2mkqc4w.

It is clear from the interviews that field sampling personnel should wear clean survey clothing, hoods, masks, shoe covers and disposable gloves. The hood must be wrapped around the hair and the gloves must be worn over the cuffs to prevent the surveyor from contaminating the biological evidence at the scene. As different experts have different abilities to extract DNA samples, there is a risk of damage to the DNA samples during the extraction process, which directly affects the outcome of the DNA identification and thus the direction of the criminal case.

2.1.5.2Flaws in DNA Sample Delivery and Storage

By interviewing forensic examiners from the Serious Crime Unit, forensic examiners are required to take each DNA sample, individually packaged and numbered, after it has been extracted from the crime scene, and to take care of the protection of the DNA samples during transport from the crime scene back to the biological laboratory. In the process of transport, you should avoid DNA tests rubbing against each other, ramming and preventing fragile test materials from being crushed and shaken. At the same time, the containers should be kept clean and uncontaminated before using. During the transport of DNA samples, it is important not to open the samples and observe, breathe, talk or even touch them, and to return to the biological laboratory for all use of the samples. DNA contamination can lead to the mixing of new DNA information in the test material, or even affect the test of the original DNA information, affecting the accuracy of the identification findings. It creates difficulties in the identification or exclusion of suspects, which misleads the direction of the investigation and is detrimental to improving the efficiency of solving criminal cases. The interviewer also emphasised that the time of delivery has a great impact on the analysis findings. The detection rate of DNA and the time of delivery are almost positively correlated, the earlier the delivery time the higher the detection rate, and the later the delivery time the lower the detection rate.

It is particularly important to create a suitable storage environment for DNA samples. This is because the storage environment directly affects the accuracy of DNA analysis results. Each specimen has different temperature and environmental requirements, solid and liquid specimens are stored

differently, as are the containers in which the specimens are held and the methods of storage. For example, hair and stain type specimens should be placed in a cool dry place or stored at -20°C after drying; liquid type specimens should be stored in specific containers, and blood type should be stored at -20°C with the necessary anticoagulation measures; frozen preserved materials should avoid repeated freezing and thawing, etc. It is also important to set up a special laboratory to store DNA samples, which is very helpful in protecting DNA samples.

2.1.5.3The Effect of DNA Testing Methods and Test Reagent Products on Accuracy.

At the initial stage of applying STR genetic markers, only three or six STR loci can be detected. The discrimination power is very low and the results are not very accurate and reliable. This is because the cumulative individual recognition power of testing only 6 loci is not yet sufficient to distinguish between all individuals. There is a chance that random individuals will match on all six loci, which could lead to incorrect conclusions. By 1997, the C1Tr, FFV and Silver STRTM silver stain series was being used to detect a total of 9 STR loci, but the recognition rate was limited and there was still a certain risk of false matches. With the development of technology DNA testing methods are also advancing after 2010, and there is no problem to detect 18-22 STR loci. Therefore, the cumulative individual recognition rate varies with the choice of kit, and the higher the recognition rate the more accurate the DNA test results will be.

The individual recognition rates for the different kits are shown in the following table：

TIME	Detection of autosomal STR locus numbers	Reagent kit	Recognition rate in the Han
1993	3 loci(CSF1PO, TPOX, TH01)	CTT Silver Dyeing System from Promega, USA	1:410
1997	3 loci(F13A01, FESFPS, vWA)	FFV silver dyeing system from Promega, USA	1:425
1997	3 loci(D16S539, D7S820, D13S317)	Silver STR® III from Promega, USA	1:2216
1997	9 loci(CSF1PO, TPOX, TH01, F13A01, FESFPS, vWA, DI6S539, D7S82O and D13S317)	Combined detection of CTT, FFV, Silver STRTM silver staining system	$1:3.9x10^{8}$
1997	9 loci(D3S1358, vWA , FGA, D8S1179.D21S11, D18S51,D5S818, D13S317, D7S820)	ABI Profiler® plus kit, USA	$1:9.6x10^{10}$
1998	6 loci(D3S1358, D16S539, TH01,TPOX, CSF1PO, D7S820)	ABI cofiler® kit, USA	$1:8.4x10^{8}$
2000-present	15 loci(13 core loci of CODIS+ PentaD+ PentaE)	Promega Powerplex® 16, , USA	$1:1.8x10^{17}$
2001-present	15 loci（13 core loci of CODIS+ D2S1338+ D19S433）	ABI Identifier® kit, USA	$1:7.64x10^{17}$
2004-present	14 loci(11 core loci of CODIS+ D6S1043+ D2S1338+ PentaE)	DNATyper™15,Ministry of Public Security, China	$1:3.759x10^{17}$
After 2010	18-22 loci(13 core loci of CODIS+D6S1043,D2S1338,D19S433,PentaD,PentaE,D12S391, D1S1656,D1OS1248,D2S441 etc..)	DNATyper™15 plus,Ministry of Public Security, China；Goldeneye20A； Promega PowerPlex® 21 System & PowerPlex® Fusion； AGCU E22 etc..	$>1:1.0x10^{21}$

Table 1 Forensic Physical Evidence Examination in China at Different Times

The forensic scientist interviewed at the same time told me briefly that every provincial forensic centre and public security system in China is currently equipped with a capillary electrophoresis instrument, which works on the basis that DNA molecules are themselves negatively charged and will surge towards the positive pole in the electrophoresis instrument. The PCR products are first coated with a fluorescent dye and then the fluorescent dye is excited by a laser at the CCD Panel, and the fluorescently labelled DNA fragments are separated according to their molecular weight and subsequently captured and recorded by the computer. However, care must be taken that, firstly, the length ranges of the PCR fragments produced at each site do not cross over on one colour of fluorescence and that a small length spacing is left between each other to avoid interference between PCR products from different sites. Secondly, the length of the PCR amplification fragment should not be too long, as forensic testing often encounters samples of very poor quality and severely degraded DNA, for such samples, the shorter the PCR fragment the easier it is to be amplified, while too long PCR fragments are difficult to be amplified, so the longest PCR amplification fragment in the kit is controlled below 440 bases, and even some lengths are controlled within The longest PCR amplification fragment in the kit is controlled to be below 440 bases, or even 220 bases in some

cases, to achieve better differentiation.

2.1.5.4Professionalism of Forensic Physicians

The expertise of the forensic physician also has a direct impact on the authenticity of the DNA evidence, and as the survey shows, "most genotyping errors are more or less human-related ..... up to 93% of errors are due to human factors... ...even in automated and semi-automated typing processes for fluoroscopy, typing errors cannot be completely avoided."

As an integral part of criminal investigation, DNA identification techniques are distinctly professional and involve complex procedures that require a thorough knowledge of DNA biology and the ability to operate the relevant equipment in a DNA laboratory. In other words, the accuracy of DNA does not depend solely on its science, but rather on a series of processes by the identifier that has a significant impact on the accuracy of the DNA. This is because it is people who operate the machines that use DNA identification techniques. Sometimes an inadvertent action, forgetting a reagent, or confusing a step, can lead to inaccurate results, which can have incalculable consequences during the investigation, prosecution and trial process.

2.1.5.5DNA Molecules' Properties on Accuracy and Reliability

In-depth conversations with the forensic scientists interviewed revealed that some of the biological properties of DNA, a large biological molecule, often have a greater impact on the results than the technical aspects of the analysis.

Firstly, we talked about Degrade DNA, a phenomenon in which DNA degrades into small fragments when exposed to water or sunlight, making it impossible for forensic examiners to amplify the fragments to complete a DNA fingerprint. Such situations often bring us very close to the truth but are not technically possible to provide accurate fingerprinting evidence.

Secondly, DNA Transfer. This concept means that a person may leave a biological trace in a place

even if he or she has not been there. In daily life, it is always difficult to avoid transferring our DNA from different objects, places and people. So the DNA found at a crime scene may belong to someone who has not been there. In Germany, there was a series of cases where different types of crimes were committed and there was no commonality between the cases, but the same DNA was found at each crime scene. After 16 years of investigation, the European police discovered that the series had come from a worker who, while in charge of making swabs for crime scene forensics, had accidentally contaminated an entire batch of swabs, which were subsequently distributed to criminal investigators everywhere. This situation can seriously affect the reliability of DNA identification results.

Finally, we talked about the phenomenon of mosaic. The simultaneous presence of two or more cell lines of different karyotypes in a single individual, all of which survive and do not exhibit characteristics. Most mosaics in the world are congenital mosaics; they exist in the womb. When a mother conceives twins from different eggs, if one embryo dies prematurely, then the other embryo consumes part of the dead embryo's cells and the surviving embryo grows into a baby with two types of DNA, which are permanently distributed in different areas of the baby's body, sharing a common body. In the world, others are forced to be formed later in life, such as bone marrow transplants. If the situation is not adequately taken into account in a criminal case, it is likely to lead to the wrong conclusion.

2.1.6PRECAUTIONS AND RECOMMENDATIONS

2.1.6.1Robust DNA Database

Normally the DNA database of Chinese public security authorities contains five basic databases. The first is a database of ex-convicts storing suspects with previous convictions for sexually violent crimes; the second is a scene evidence database storing DNA typing data for various types of biological examinations left at crime scenes that are of value; the third is a DNA database of unidentified bodies, and the fourth is a DNA database of relatives of missing persons.[40] The fifth is a

[40] Starinsky-Elbaz, Sigal, Tal Ariel, and Yossi Issan. 2019. “DNA Kinship Analysis of Unidentified Human Remains That Led to a Murder Investigation.” *Forensic Science International* 300 (July): e20–23. https://doi.org/10.1016/j.forsciint.2019.03.045.

basic DNA database that mainly stores the chromosomal positioning of various genetic motifs, gene frequency and genotype information of relevant groups, and relevant forensic application parameters.[41]

Whereas the Y-STR gene bank is not well established, as mentioned earlier, Y-STR technology is more useful for criminal investigations because many crime subjects are male. The use of Y-STR genetic technology, however, relies heavily on the creation of genetic databases and genetic census work. If a murder is committed by a distant outsider and the Y-STR gene database does not cover the person's genetic information, then even if the Y-STR genetic profile of the suspect is obtained, the case cannot be solved in time. Therefore, to enrich the Y-STR gene matching resources, the link between official databases and private databases and private fragmented big data should be strengthened continuously. The Y-STR data detected by private databases, hospitals, research institutions and even private citizens for medical treatment, scientific research and DNA identification can be of great help in solving cases. In the process of investigating specific cases, after using the Y-STR genetic database to identify suspect groups, investigators can communicate and compare data with other official databases, private databases and scattered private data, to use the advantages of big data quickly and accurately find specific suspects and improve the rate of solving cases. To maximize the role of DNA databases in detecting and solving crimes, it is necessary to establish an efficient and unified DNA database and truly realize data sharing.

2.1.6.2Standardisation of Technical Standards and Professionalism of the Identification

Inconsistencies in the identification standards of identification agencies make different conclusions, often resulting in a waste of judicial identification resources, and therefore the cost to regulate these is very necessary. For identification standards, this requires the integration and exploration of resources in all areas, which should not only be combined with technical standards at the same time

[41] Gonzalez-Galarza, Faviel F, Antony McCabe, Eduardo J Melo dos Santos, James Jones, Louise Takeshita, Nestor D Ortega-Rivera, Glenda M del Cid-Pavon, et al. 2019. “Allele Frequency Net Database (AFND) 2020 Update: Gold-Standard Data Classification, Open Access Genotype Data and New Query Tools.” *Nucleic Acids Research*, November. https://doi.org/10.1093/nar/gkz1029.

as forensic identification but also require the joint discussion of judicial experts, which I think is a long-term process of gradual improvement, rather than a quick fix. At present, the Chinese public security authorities have drafted the Court Scientific DNA Laboratory Specification and the Court Scientific DNA Database Construction Specification, both of which are based on technical aspects. There is still a lack of strict legal norms governing DNA sampling procedures and the scope of sampling.

In terms of personnel regulation, this is an easier aspect to achieve than the standard regulation of identification, but it is also more uncertain because it is the personnel who are managed. I believe that in addition to reasonable organisational rules, supervision mechanisms are an important part of the process, such as DNA collection procedures, custody transfer procedures, and identification procedures, all of which require the development of responsibility norms, the supervision of procedural integrity, and the implementation of lifelong responsibility mechanisms, which may seem more cumbersome, but to ensure the impartiality of the conclusions, and to make the identification can reach the level of once in place, the payment It is worth the effort, after all, the technology is constantly evolving and the quality of the personnel should be constantly improved.

2.1.6.3Bridging the Legislative Gap in The Field of DNA

The DNA Identification Act was passed by the US Congress in 1994 to regulate the validation of DNA experiments, proficiency testing, laboratory modifications and the quality of DNA identification, and the DNA Sample Extraction Regulations were issued by the UK Home Office in 1995. In Canada, the DNA Identification Regulations were passed in July 2000 to establish a DNA database of all confirmed offenders. The enactment of these acts and regulations has made DNA identification lawful.

In contrast, in China, there are only relevant national standards and technical specifications for the application of DNA identification findings, but the national standards and technical specifications are not part of the law and have no mandatory enforcement power. Therefore, China's current legislation on DNA is still a "gap". DNA in the application of criminal investigation on the lack of legal norms,

the system is not perfect, so the application of DNA identification technology presents an unrestrained state, which will easily cause the consequences of judicial practice at a loss. Strictly speaking, for the whole process of sampling, evidence collection, identification and application of conclusions by investigators, specific legislation is needed to regulate. Therefore, China should speed up the legislation in the field of DNA, and at the same time establish a regular training mechanism for relevant personnel on the law, and regularly assess the legal literacy of identification personnel.

3. CONCLUSION

" Locard Exchange Principle," tells us that as long as the perpetrator commits a crime, he or she will inevitably act directly or indirectly on the object being attacked and its surroundings at the crime scene, leaving traces consciously or unconsciously. DNA technology is through the collection of biological traces left by the perpetrator at the scene, and then made full use of modern biological science and technology, and finally, clear the suspect and crime, become a powerful assistant of public security organs to combat crime. Compared with other physical evidence techniques, DNA analysis technology has a solid theoretical foundation, mature operating techniques and highly automated testing instruments, and DNA evidence is the most persuasive of all scientific evidence. It often plays a key role in the identification of criminal cases, civil disputes and large catastrophic events, providing a scientific and technological means to combat crime and clear wrongdoing, safeguarding the legitimate rights and interests of the parties involved and ensuring social stability. However, as analysed in this paper, even without taking into account the presence of switched and replaced samples in the chain of evidence, contamination, or apparent errors in laboratory testing, the type of DNA genetic markers we test, the size of the identification capacity of the test system, the sensitivity and accuracy of the test method, the determination of relatedness by genetic mutations, and the limitations of consanguinity and homozygous polyploidy are factors that affect the final identification opinion when analysed from a technical point of view only. In addition, the professional quality of the identification personnel is also very important. At present, China's DNA identification qualified laboratories do not account for a minority of institutions in the identification

of good and bad personnel, the difficulty of the case and the potential risk of underestimation, the test is not in place, the accuracy and objectivity of the identification opinion is difficult to ensure. All these things. We need to break the DNA is ironclad evidence mode of thinking, in the spirit of science to face DNA evidence, neither to push it to the altar. We should not cast doubt on the nature of DNA evidence because of individual errors.

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