



Role of DNA in Forensic Genetics: Techniques and Applications

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DESCRIPTION

DNA (Deoxyribonucleic Acid) the genetic code has transformed forensic science by offering a potent instrument for person identification, criminal investigation, and innocent person exoneration. The genetic material found in humans and nearly all other species is called deoxyribonucleic acid. Every individual's DNA is unique making it an invaluable resource in forensic investigations. Forensic genetics involves analyzing DNA samples to identify individuals, establish familial relationships, and provide evidence in criminal cases.

Techniques in forensic DNA analysis

Several techniques have been developed to analyze DNA in forensic contexts, each offering varying degrees of specificity and applicability.

Restriction Fragment Length Polymorphism (RFLP): RFLP was one of the first methods used in forensic DNA analysis. It involves cutting DNA into fragments using restriction enzymes, separating these fragments by gel electrophoresis, and then identifying specific patterns using probes. While RFLP provides highly discriminative results, it requires relatively large and high-quality DNA samples, limiting its use in forensic cases where DNA may be degraded or available in small quantities.

Polymerase Chain Reaction (PCR): PCR revolutionized forensic DNA analysis by enabling the amplification of specific DNA regions from tiny samples. This technique can generate millions of copies of a DNA segment, making it possible to analyze samples that are old, degraded, or extremely small.

Short Tandem Repeats (STR) analysis: STR analysis is the most widely used technique in forensic genetics. The number of repeats varies between individuals, making STRs highly polymorphic and ideal for identity testing. STR analysis involves amplifying these regions using PCR and then separating and visualizing the fragments through electrophoresis. The resulting STR profiles can be compared to databases to identify individuals or establish genetic relationships.

Mitochondrial DNA (mtDNA) analysis: mtDNA analysis is useful in cases where nuclear DNA is highly degraded or unavailable, such as in old skeletal remains. mtDNA is inherited maternally and is present in multiple copies per cell, increasing the likelihood of obtaining a usable sample. While mtDNA analysis is less discriminative than nuclear DNA analysis due to its maternal inheritance pattern, it can still provide valuable information in forensic investigations.

Y-Chromosome analysis: Y-chromosome analysis focuses on the male-specific Y chromosome, which is passed from father to son with little recombination. This technique is particularly useful in cases involving male perpetrators, such as sexual assaults, and for tracing paternal lineages. Y-STR analysis, which examines STRs on the Y chromosome, can help differentiate male DNA in mixed samples and establish paternal relationships.

Next-Generation Sequencing (NGS): NGS also known as massively parallel sequencing, is a cutting-edge technology that allows for the sequencing of entire genomes or targeted regions at high throughput. NGS provides comprehensive genetic information and can analyze complex mixtures of DNA. In forensic genetics, NGS is being explored for its potential to analyze degraded samples, provide additional discriminatory power through Single Nucleotide Polymorphisms (SNPs) and offer insights into ancestry and physical traits.

Applications of forensic DNA analysis

Forensic DNA analysis has a wide range of applications, from criminal investigations to disaster victim identification and beyond.

Criminal investigations: DNA analysis has become a modern criminal investigations. DNA evidence can link a suspect to a crime scene, victim, or weapon, providing crucial information for solving cases. The use of DNA databases, such as CODIS (Combined DNA Index System) in the United States, allows for the comparison of DNA profiles from crime scenes with profiles of known offenders and arrestees, facilitating the identification of repeat offenders and cold cases.

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Exoneration of the innocent: DNA evidence has played a pivotal role in exonerating individuals convicted of crimes. Organizations like the Innocence Project have used DNA testing to review and overturn wrongful convictions, highlighting the importance of accurate forensic analysis in the justice system. DNA evidence can definitively exclude individuals as perpetrators, providing a powerful tool for ensuring justice.

Disaster victim identification: DNA analysis is critical in identifying victims of mass disasters, such as natural disasters, terrorist attacks, and accidents. Traditional identification methods, such as visual identification and dental records, may be insufficient in such scenarios. This process provides closure for families and aids in the proper management of disaster aftermaths.

Missing persons and unidentified remains: forensic DNA analysis is instrumental in identifying missing persons and unidentified remains. DNA profiles from unidentified bodies can be compared to DNA from relatives of missing individuals to establish identity. National and international databases help facilitate these comparisons, aiding in the resolution of long-standing missing persons cases.

Biological relationship testing: DNA analysis can establish biological relationships, such as paternity, maternity, and sibling relationships. This is important in legal contexts, such as child custody disputes, immigration cases, and inheritance claims. DNA testing provides definitive evidence of familial relationships, ensuring accurate and fair legal outcomes.

Wildlife and environmental forensics: Forensic DNA analysis extends beyond human identification to wildlife and environmental forensics. DNA testing can identify species, determine the origin of animal products, and combat illegal wildlife trade.

The role of DNA in forensic genetics is deep, offering unparalleled tools for identifying individuals, solving crimes, and ensuring integrity. Advances in DNA analysis techniques, from STR and mtDNA analysis to NGS, have expanded the applications of forensic genetics and improved its accuracy and reliability. As technology continues to evolve, forensic DNA analysis will play an increasingly vital role in various fields, from criminal justice to disaster management and beyond, shaping the future of forensic science and enhancing our ability to uncover the truth.