DEOXYRIBONUCLEIC ACID: SCIENCE & TECHNOLOGY

NEWS: What is DNA fingerprinting?

WHAT'S IN THE NEWS?

DNA, a stable and unique identifier, is crucial in **forensic science** for **solving cold cases**, identifying suspects, and establishing biological relationships. Through technologies like **PCR** and **DNA fingerprinting**, it enables the analysis of archived crime scene materials, even from ancient remains, for accurate identification.

Deoxyribonucleic Acid (DNA)

What is DNA?

- **Definition**:
    - **DNA (Deoxyribonucleic Acid)** is the **genetic material** found in all living organisms and most viruses. It is the molecule that carries the genetic instructions used in the development, functioning, and reproduction of all organisms. It is the blueprint that determines the structure and function of the organism.
    - DNA is the **hereditary material**, meaning it is passed from one generation to the next, providing the genetic instructions for the development of the organism.
- **Location**:
    - **Nuclear DNA** is found primarily in the **nucleus of the cell**. The **nucleus** is the central part of a cell that holds the genetic material and controls cell activities.
    - Additionally, **mitochondrial DNA** is found in **mitochondria**, which are the energy-producing structures in the cell. While mitochondrial DNA is inherited only from the mother, nuclear DNA is inherited from both parents.
- **Structure**:
    - DNA has a **double-helix structure**, meaning it consists of two long strands of nucleotides twisted around each other. These strands are held together by **base pairs**. The four bases in DNA are **adenine (A)**, **guanine (G)**, **cytosine (C)**, and **thymine (T)**. Adenine pairs with thymine (A-T) and cytosine pairs with guanine (C-G), forming **base pairs** that form the structure of DNA.

DNA's Role in Identification

- **Biological Fingerprint**:

- DNA acts as a **unique identifier**, similar to a **biometric fingerprint** for humans. Every individual has a distinct DNA sequence, which makes it an excellent tool for **personal identification**.

- Just as the **Aadhaar number** is used to uniquely identify individuals in India, **DNA** can be used to confirm identity in a forensic context, **identifying suspects**, or **exonerating wrongfully accused individuals**.

- **Presence in Every Cell**:

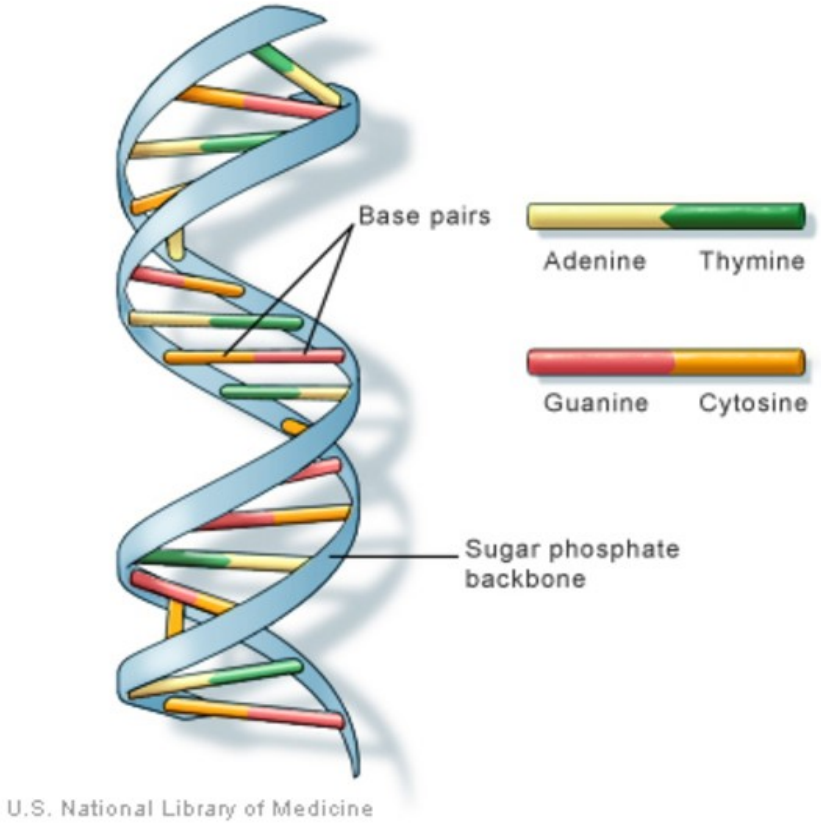
  - **DNA is present in every cell** in the human body, and each cell contains **46 chromosomes**—23 inherited from the **mother** and 23 from the **father**.

  - The **chromosomes** are long strands of DNA that carry **genetic information**. The DNA is the **instruction manual** that tells the cell how to grow, survive, and replicate.

- **Packed in Chromosomes**:

  - **DNA** is **packed** into **chromosomes** within the cell nucleus. For instance, **chromosome 3** contains **6.5% of the total DNA** in the human body.

  - This DNA encodes the genetic information needed for the organism's growth and development.



Polymorphism in DNA

- **Polymorphisms**:
    - **Polymorphisms** refer to **genetic variations** in the DNA sequence among individuals or populations. These variations can be as small as a single nucleotide change (SNP - single nucleotide polymorphisms), or larger structural changes.
    - These genetic differences can be inherited from the **parents** and are responsible for the **individual differences** in appearance, behavior, and health.
- **Importance of Polymorphism**:
    - These polymorphisms help in **identifying** individuals because the genetic sequence can vary even between unrelated individuals. This makes it possible to use DNA as a **forensic tool** to identify individuals involved in a crime or resolve family relationships (like paternity testing).

Short Tandem Repeats (STRs)

- **STRs Definition**:
    - **Short Tandem Repeats (STRs)** are **short DNA sequences** that are repeated multiple times in a row. For example, the sequence **GATC** might be repeated multiple times: **GATCGATCGATC**.
    - These sequences are **polymorphic**, meaning the number of repeats can vary widely between individuals. This variability makes STRs extremely useful in **DNA profiling** and **forensic identification**.
- **STRs in Forensic Science**:
    - STR analysis is commonly used in forensic investigations because it provides a high level of **genetic variation** among individuals, even in cases where only small amounts of DNA are available.
    - STRs are used in **DNA fingerprinting** to match crime scene DNA with individuals in a database or to identify victims in mass disasters.

Polymerase Chain Reaction (PCR)

- **PCR Overview**:
    - **Polymerase Chain Reaction (PCR)** is a technique used to **amplify (copy)** specific DNA sequences, even from **minute amounts of DNA**. This is essential when forensic scientists only have a small sample of DNA to work with.

- **Steps in PCR**:

    1. **DNA Denaturation**: The DNA sample is heated to **separate the two strands**.

    2. **Binding Primers**: Short DNA sequences (primers) are added, which bind to the specific **target sequences** on the DNA strands.

    3. **DNA Replication**: **DNA polymerase** is used to replicate the DNA sequence between the primers, making **millions of copies** of the targeted DNA segment in a matter of **minutes** (typically about **50 minutes**).

- **PCR Significance**:

    - PCR is **critical** in forensic science because it can amplify DNA even from **deteriorated or limited samples**. For example, a small fragment of DNA from a crime scene can be amplified enough to create a full profile for identification.

Applications of DNA Fingerprints

- **Forensic Science**:

    - DNA fingerprinting plays a **crucial role** in **forensic science** by helping to **identify criminals**, **exonerate innocent individuals**, and solve **cold cases**. It is also useful for confirming the identity of a **suspect** or **victim** in **violent crimes**, including **murders** and **sexual assaults**.

- **Paternity Testing**:

    - DNA is widely used in **paternity testing** to establish biological relationships between a father and his child, confirming **family ties** with great precision.

- **Disaster Victim Identification**:

    - DNA identification is essential in **disaster victim identification**, such as in **natural disasters** (earthquakes, floods) or **terrorist attacks**, where bodies may be too damaged for traditional identification methods.

- **Organ Donation Matching**:

    - DNA fingerprints are also useful for matching **organ donors** with **recipients**, ensuring compatibility and reducing the risk of organ rejection.

- **Cold Cases**:

    - **Cold cases**, which are **unsolved criminal cases**, can be reopened using **archived DNA evidence**. Advances in **DNA profiling** allow forensic scientists to revisit old evidence, identify new suspects, or clear wrongly accused individuals.

Importance of DNA in Crime Solving

- **Stability and Longevity**:
    - DNA is **highly stable**, even under adverse conditions. It has been successfully extracted from **ancient human remains**, such as from remains that are **65,000 years old**.
    - This stability ensures that DNA can be used to **solve crimes** from archived materials, providing a way to revisit **old crime scene evidence** that might not have been useful with previous technology.
- **Relevance in Solving Cold Cases**:
    - DNA's stability allows it to remain intact over long periods, which makes it invaluable in solving **cold cases**—criminal investigations that have been unresolved for years. **Profiles from archived crime scene materials** can be reanalyzed with modern DNA technology, leading to the identification of perpetrators or the clearing of wrongly accused individuals.

Conclusion

- **DNA** plays a **pivotal role** in modern **forensic science**, providing a reliable method for **identifying individuals**, **solving cold cases**, and establishing biological relationships.
- Advances in **DNA fingerprinting** and **PCR** technology continue to enhance its application in **law enforcement** and **genetic research**, making it one of the most valuable tools in the **criminal justice system**.

Source: **https://www.thehindu.com/sci-tech/science/what-are-dna-polymorphisms-and-how-do-they-differentiate-between-people/article69369159.ece**