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PRACTICAL APPLICATIONS OF DNA FINGERPRINTING

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Abstract
The discovery of the structure of DNA in the first half of this century established the foundation for genetic engineering and DNA technologies with unexpected applications. The body of an individual is composed of 100 trillion cells. All these cells whether from blood, bone, saliva, seminal or vaginal secretions, hair roots, brain tissue, teeth pulp or any other tissue of an individual have identical biological information. In DNA fingerprinting scientists exploit this biological specificity. Like the fingerprints that came into use by detectives and police labs during the 1930s, each person has a unique DNA fingerprint. Unlike a conventional fingerprint that occurs only on the fingertips and can be altered by surgery, a DNA fingerprint is the same for every cell, tissue, and organ of a person. It cannot be altered by any known treatment. In this paper, the author has described meaning, methods and procedure of making the DNA fingerprinting and has explained its practical application and the problems faced during DNA fingerprinting. In conclusion, it has been suggested that with the help of new scientific technology crime investigation methods could be improved and law enforcement could be strengthened.

Key words: DNA Fingerprinting, Personal Identifications, Inherited Disorders, VNTR pattern, Criminal Identification.

1 Introduction

As we look back on the history of science, the development of new technologies in science has found applications in areas as varied and diverse as sociology, economics, mathematics and statistics. The discovery of the structure of DNA in the first half of this century established the foundation for genetic engineering and DNA technologies with unexpected applications. Although, the impact of these technologies in different countries has been different, globally the unprecedented and unimaginable gains provided by gene technologies have provided several benefits.

The body of an individual is composed of 100 trillion cells. All these cells whether from blood, bone, saliva, seminal or vaginal secretions, hair roots, brain tissue, teeth pulp or any other tissue of an individual have identical biological information. This information has to match with either of the biological parents because the first cell was their joint contribution. The individualistic constitution of the parents; the meiotic processes and their random union during fertilization; ensures that except for monozygotic twins no two individuals would ever have exactly the same biological constitution. In DNA fingerprinting scientists exploit this biological specificity.[1]

Like the fingerprints that came into use by detectives and police labs during the 1930s, each person has a unique DNA fingerprint. Unlike a conventional fingerprint that occurs only on the fingertips and can be altered by surgery, a DNA fingerprint is the same for every cell, tissue, and organ of a person. It cannot be altered by any known treatment. Consequently, DNA fingerprinting is rapidly becoming the primary method for identifying and distinguishing among individual human beings.[2]

The term `DNA fingerprinting' could be applied to any approach to detecting individual variation through analysis of DNA. It has, however, come to be associated with a particular method based around the technique of 'Southern' blotting. The application of this procedure has been widely acclaimed as a major breakthrough in forensic science, although its use has not been without criticism in some instances. The power of the method to discriminate between individuals derives from the use of DNA probes that identify highly variable regions of the genome, usually short tandemly repeated sequences or minisatellites. These regions are sufficiently variable that the probability of false identity is negligible, thus allowing positive identification to be made with confidence.[3]

1. The biological information is stored in the DNA that has four nucleotide bases, of which two are puries-adenine (A) and guanine (G); and two are pyrimidines-thymine (T) and cytosine (C). For further details, see: Bhanwer, AJS, Arvind Rup Singh and Jai Rup Singh (2001) Journal of Punjab Academy of Forensic Medicine & Toxicology, Vol. 1, No. 1, "DNA Fingerprinting in Forensic and Medico-Legal Applications", pp. 22-29 at p. 22.
2. Betsch, David F., http://www.accessexcellence.org/AB/BA/DNA_Fingerprinting_Basics.html, "DNA Fingerprinting in Human Health and Society", Accessed on 26 March 2017.
3. http://www.biology.washington.edu/fingerprint/dnaintro.html, Accessed on 19 March 2017.

In this paper, the author has described meaning, methods and procedure of making the DNA fingerprinting and has explained its practical application and the problems faced during DNA fingerprinting. In conclusion, it has been suggested that with the help of new scientific technology crime investigation methods could be improved and law enforcement could be strengthened.

2 What is DNA Fingerprinting?

Deoxyribonucleic Acid (DNA)[4] is the fundamental building block for an individual's entire genetic makeup. It is a component of virtually every cell in the human body. It is contained in blood, semen, skin cells, tissue, organs, muscle, brain cells, bone, teeth, hair, saliva, mucus, perspiration, fingernails, urine, etc. Further, a person's DNA is the same in every cell. For example, the DNA in a man's blood is the same as the DNA in his skin cells, semen, and saliva.[5]

It seemed strange at one point, but we've grown to accept the idea that each person's fingerprints are unique. Today, "fingerprint" defines the perfect identification technique, and when we use DNA to conclusively identify someone, we call the process "DNA fingerprinting."[6] The term 'fingerprint' usually refers to the patterns on the fingerballs and this has been used since ages for the individual identification. Fingerprint also refers to the map of peptides generated after electrophoresis and chromatography of proteins. With the advent of molecular technologies this has been referred to a print generated by a multilocus probe after hybridization with DNA thus leading to the term DNA Fingerprinting. The basic material for studying DNA fingerprinting is the genomic DNA. Its source could be fresh blood, dried blood stain, buccal cells, saliva stains, hair roots, urine, bones or remains of bones, pulp of teeth, semen or vaginal smears, etc. The modern molecular biology techniques enable us to study the variations in the DNA obtained from any of these sources.[7]

The chemical structure of everyone's DNA is the same. The only difference between people (or any animal) is the order of the base pairs. There are so many millions of base pairs in each person's DNA that every person has a different sequence. Using these sequences, every person could be identified solely by the sequence of their base pairs. However, because there are so many millions of base pairs, the task would be very time-consuming. Instead, scientists are able to use a shorter method, because of repeating patterns in DNA. These patterns do not, however, give an individual "fingerprint," but they are able to determine whether two DNA samples are from the same person, related people, or non-related people. Scientists use a small number of sequences of DNA that are known to vary among individuals a great deal, and analyze those to get a certain probability of a match.[8]

2.1 Making DNA Fingerprints

DNA fingerprinting is a laboratory procedure that requires six steps:

(a) Isolation of DNA

DNA must be recovered from the cells or tissues of the body. Only a small amount of tissue - like blood, hair, or skin - is needed. For example, the amount of DNA found at the root of one hair is usually sufficient.

(b) Cutting, sizing, and sorting

Special enzymes called restriction enzymes are used to cut the DNA at specific places. For example, an enzyme called EcoR1, found in bacteria, will cut DNA only when the sequence GAATTC occurs. The DNA pieces are sorted according to size by a sieving technique called electrophoresis. The DNA pieces are passed through a gel made from seaweed agarose (a jelly-like product made from seaweed). This technique is the biotechnology equivalent of screening sand through progressively finer mesh screens to determine particle sizes.

4. Ironically, DNA was discovered in 1869, only ten years after the publication of Darwin's Origin of Species and four years after Mendel's "Experiments in Plant-Hybridization". An enterprising German doctor, Friedrich Miescher, isolated a substance he called "nuclein", from the large nuclei of white blood cells. His source of cells was pus from soiled surgical bandages. However, DNA Science is said to have been born on 25 April 1953 when James Watson and Francis Crick announced in the British Journal Nature that they had determined the "Double Helix" structure of the DNA molecule. The DNA era came of age in 2001 with the publication of a draft of the human genome, the entire DNA code that sets the parameters of human life. For further details, see: David A. Micklos, Greg A. Freyer and David A. Crotty (2003) DNA Science A First Course, Cold Spring Harbor Laboratory Press, New York, p. 30.
5. http://www.ncjrs.org/nij/DNAbro/intro.html, Accessed on 17 March 17.
6. http://whyfiles.org/014forensic/index.html, Accessed on 26 March 2017.
7. See: Bhanwer, AJS, Arvind Rup Singh and Jai Rup Singh (2001), p. 23.
8. http://www.biology.washington.edu/fingerprint/dnaintro.html, Accessed on 19 March 17.

(c) Transfer of DNA to nylon: The distribution of DNA pieces is transferred to a nylon sheet by placing the sheet on the gel and soaking them overnight.

(d) Probing: Adding radioactive or colored probes to the nylon sheet produces a pattern called the DNA fingerprint. Each probe typically sticks in only one or two specific places on the nylon sheet.

(e) DNA finger print: The final DNA fingerprint is built by using several probes (5-10 or more) simultaneously. It resembles the bar codes used by grocery store scanners.[9]

3 Practical Applications of DNA Fingerprinting

The major applications of DNA fingerprinting is in the medico-legal cases, such as paternity-maternity disputes, rape cases, murder cases, bomb blast or war crime cases, killings by dictators as well as to diagnose inherited disorders and to develop cure for these disorders etc. In most of the forensic cases, the main goal is to assign positive identification of the evidentiary material with those of the putative suspects. It may not prove guilt but might throw more light on the evidence, which is the basic requirement in the court.

(a) Paternity and Maternity: However, a person inherits his or her Variable Number Tandem Repeats (VNTRs)[10] from his or her parents. VNTRs patterns can be used to establish paternity and maternity. The patterns are so specific that a parental VNTRs pattern can be reconstructed even if only the children's VNTRs patterns are known (the more children produced, the more reliable the reconstruction). Parent-child VNTRs pattern analysis has been used to solve standard father-identification cases as well as more complicated cases of confirming legal nationality and, in instances of adoption, biological parenthood. Another important use of DNA fingerprints in the court system is to establish paternity in custody and child support litigation. In these applications, DNA fingerprints bring an unprecedented, nearly perfect accuracy to the determination.

(b) Criminal Identification and Forensics: DNA isolated from blood, hair, skin cells, or other genetic evidence left at the scene of a crime can be compared, through VNTRs patterns, with the DNA of a criminal suspect to determine guilt or innocence. VNTRs patterns are also useful in establishing the identity of a homicide victim, either from DNA found as evidence or from the body itself.

(c) Personal Identifications: The notion of using DNA fingerprints as a sort of genetic bar code to identify individuals has been discussed, but this is not likely to happen anytime in the foreseeable future. The technology required to isolate, keep on file, and then analyze millions of very specified VNTR patterns is both expensive and impractical. Social security numbers, picture ID, and other more mundane methods are much more likely to remain the prevalent ways to establish personal identification.[11] The DNA method will be far superior to the dogtags, dental records, and blood typing strategies currently in use.

(d) Diagnosis of Inherited Disorders: DNA fingerprinting is used to diagnose inherited disorders in both prenatal and newborn babies in hospitals around the world. These disorders may include cystic fibrosis, hemophilia, Huntington's disease, familial Alzheimer's, sickle cell anemia, thalassemia, and many others. Early detection of such disorders enables the medical staff to prepare themselves and the parents for proper treatment of the child. In some programs, genetic counselors use DNA fingerprint information to help prospective parents understand the risk of having an affected child. In other programs, prospective parents use DNA fingerprint information in their decisions concerning affected pregnancies.[12]

(e) Developing Cures for Inherited Disorders: Research programs to locate inherited disorders on the chromosomes depend on the information contained in DNA fingerprints. By studying the DNA fingerprints of relatives who have a history of some particular disorder, or by comparing large groups of people with and without the disorder, it is possible to identify

9. http://www.accessexcellence.org/AB/BA/DNA_Fingerprinting_Basics.html, Accessed on 26 March 2004.
10. Every strand of DNA has pieces that contain genetic information which informs an organism's development (exons) and pieces that, apparently, supply no relevant genetic information at all (introns). Although the introns may seem useless, it has been found that they contain repeated sequences of base pairs. These sequences, called Variable Number Tandem Repeats (VNTRs), can contain anywhere from twenty to one hundred base pairs. For further details, see: id.
11. http://www.accessexcellence.org/AB/BA/DNA_Fingerprinting_Basics.html, Accessed on 26 March 2017.

DNA patterns associated with the disease in question. This work is a necessary first step in designing an eventual genetic cure for these disorders.[13]

Syed Hasnain, Director, Centre for DNA Fingerprinting and Diagnostics (CDFD)[14], said there was an urgent need to create a genetic database of criminals in the country based on their deoxyribonucleacacid (DNA) profile.

It has been observed that whenever DNA is presented as evidence, the conviction rates have gone up to 90 per cent. In contrast, the average conviction rate in the normal system was around 10 per cent. The CDFD has been getting one case per day on average to use DNA fingerprinting. It had so far addressed 1000 cases. Since, the lab cannot handle large numbers, expertise has been created in the Central Forensic Sciences Laboratories (CFSL) also. The databases should clearly address privacy issues, he said. There is also a need to look into the new legal rights issues that could emerge with children born to surrogate mothers, cloned babies in the near future. The Indian Law also needs to incorporate DNA as evidence in the Indian Penal Code (IPC) to give momentum. At present, DNA evidence is used as an expert advise by courts, he said.[15]

4 Problems with DNA Fingerprinting

Like nearly everything else in the scientific world, nothing is assured about DNA fingerprinting. The term DNA fingerprint is, in one sense, a misnomer: it implies that, like a fingerprint, the VNTR pattern for a given person is utterly and completely unique to that person. Actually, all that a VNTR pattern can do is present a probability that the person in question is indeed the person to whom the VNTR pattern (of the child, the criminal evidence, or whatever else) belongs. Given, that probability might be 1 in 20 billion, which would indicate that the person can be reasonably matched with the DNA fingerprint; then again, that probability might only be 1 in 20, leaving a large amount of doubt regarding the specific identity of the VNTR pattern's owner.[16] Still, there are problems with DNA fingerprinting. First of all, samples can be contaminated by even a microscopic bit of genetic junk. That may sound trivial (unless your life is on the line), but it's not. As a group of critics have pointed out, only one-third of 60 police department DNA labs have been accredited by the American Society of Crime Directors Laboratory Accreditation Board. That's more than the commercial DNA labs, which almost all operate without accreditation.

There's another problem with DNA results - making them meaningful to a jury. "When a fingerprint expert testifies, you can actually verify that they did [make the comparison]," says forensic scientist David Stoney of the McCrone Research Institute in Chicago. "A juror can understand the idea, and see what was done." However, when a genetic fingerprinting expert testifies, he says, "the juror has no reference point. They might think, 'this guy went into the lab and did something goofy. Now I have to take his word for it." Not only is the procedure more difficult to explain, but also the evidence is almost entirely invisible. And third, the test requires a good sample that's not too small or degraded. But a new technique, using polymerase chain reaction or PCR, can amplify tiny bits of DNA and produce a faster, although less exact, result. Problem is, the method uses even smaller samples, and is thus even more subject to contamination.[17]

Actually, the probability of a DNA fingerprint belonging to a specific person needs to be reasonably high-especially in criminal cases, where the association helps establish a suspect's guilt or innocence. Using certain rare VNTRs or combinations of VNTRs to create the VNTR pattern increases the probability that the two DNA samples do indeed match (as opposed to look alike, but not actually come from the same person) or correlate (in the case of parents and children). Variable Number Tandem Repeats (VNTRs), because they are results of genetic inheritance, are not distributed evenly across all of human population. A given VNTR cannot, therefore, have a stable probability of occurrence; it will vary depending on an individual's genetic background.[18]

5 Conclusion

DNA is an extremely powerful law enforcement tool. It has convicted many persons accused of crimes. DNA may also be the most valuable tool we have for proving innocence as well and it has even caused the nation to rethink the death penalty. Obtaining a nationwide database of DNA "fingerprints" could revolutionize law enforcement identification.[19] India needs to

12. This Centre is located in Hydrabad. It represents a synthesis of quality service and state of the art basic research. The major service components of the CDFD involve DNA Fingerprinting, diagnostics and bioinformatics. For further details, see: www.asiabiotech.com, Visited on 19 March 2017.
13. http://www.thehindubusinessline.com/, Accessed on 16 March 2017.
14. http://www.biology.washington.edu/fingerprint/dnaintro.html, Accessed on 18 March 17.
15. http://whyfiles.org/014forensic/index.html, Accessed on 26 March 2017.
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propel and inculcate an even more widespread use of scientific investigation in crime, with standards set for facilities, sample collection and training of personnel at the crime scene, that could be further used for DNA analysis or other methods of scientific inquiry. This would enable that samples of blood, hair, semen, saliva, footprints and other marks at the crime scene to clinch evidence for conviction that would leapfrog quality of scientific investigation in crime. The efficacy of the investigation and high rate of conviction based on using science in criminal investigation would act as a deterrent to future crime perpetrators. As senior advocate K.T.S. Tulsi, New Delhi aptly put it: 'There is no doubting that DNA is going to overtake the law enforcement agencies by storm. No one will be able to avoid it. It is like standing on a shore and asking the waves of the sea not to come. What is required is a proper debate about the real value of DNA and whether it fits into the overall picture and what use could be made of it by investigators.'[20] In last but not least goal is to maintain public confidence in fingerprint identification.

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