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REAL-WORLD DNA APPLICATIONS

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ABSTRACT

DNA is the total genetic information of an organism, which is also called "the genetic code book". DNA was discovered six decades ago. Since, it's discovery, it has made great progress in its multiple applications in the lifetime of Dr. James Watson, one of the discoverers of DNA. It has various applications ranging from genetic engineering, nano-medicine, personalized medicine, biotechnology, sex determination, pharmacogenetics, drug development and testing, forensics, bioinformatics, anthropology, archeology, ancestry, animal production, immigration to agriculture, and cloning organisms. It expands further in host of other biological and non-biological areas among which some of them are reviewed by this article.

KEYWORDS: DNA, Biotechnology, Genetic Engineering, Forensics, Bioinformatics, Nanomedicine, Immigration, Ancestry, Pharmacy, Anthropology, Archeology

INTRODUCTION

What we are, is our DNA and what we will be, the interaction of our DNA with the environment, termed as "epigenetics".

Deoxyribose Nucleic Acid (DNA) was discovered by Francis Crick and James Watson in 1952 in England. For this discovery, the scientists received Noble Prize in Physiology or medicine. DNA has a structure of a long chain. It is an organic molecule present in the nucleus of the cell, which includes genetic information required for the development and functioning of all the living organisms. To be precise, it is a blueprint, code or recipe required for the construction of all the components of a living cell and for functioning. The shape of the DNA is like a double-helix (ladder) made up of 6 billion bases, ATCG (A stands for "Adenine", T stands for "Thymine", "C stands for"Cytosine" and "G stands for "guanine") or 3 billion base pairs. These four bases contain instructional code required for the life cycle of organisms. Three of the codes join together to make an instruction or code for protein that is responsible for performing various functions like structural (cytoskeleton), biochemical (enzymes), mechanical (muscles), DNA replication, cell signaling (hormones), and genetic. Thus, the proteins are rightly called 'work houses' of the body.

WHAT IS DNA?

Genes are made up of DNA that contains the genetic information and is responsible for the characteristics of living organisms. In 23 chromosomes, the humans have 20,000-25,000 genes, one such set from each of the parents. Somatic cells, also called 'body cells' contain 46 chromosomes (23 from each parent). Germ cells (sperm and ovum) contain only one set (23) of chromosomes. The entire DNA of an organism is called "Genome" and it contains 46 chromosomes that include 3 billion base pairs (A-T, C-G) or 6 billion letters (ATCG). Genome is like a *code* *book or instruction book,* which contains 23 chapters. Genes on each chromosome is like a paragraph in the chapter (20-25,000) and bases are the alphabets (ACTG) in each paragraph that build meaningful words and sentences. Among the entire DNA population, only 5% is coding (*exons* that carry instructions for protein formation). The remaining 95% of DNA is junk, which is carried out from our ancestors. It is now known that some portions of junk DNA are regulating the coding process (*introns*). It is found that, the human genome contains about 20-25,000 genes, which comprises only 3% of the genome, approximately. The expression of genes results in the production of proteins to be made in a cell. This process is tightly regulated so that the cells respond to the changes in the environment and also for meeting the cells' requirements. DNA contains a large amount of non-functional and non-coding sequences. These stay switched off and have mutated genes or the ones inserted from other creatures during evolution, e.g., bacteria and viruses.

All the human beings have 99.9% of similar DNA and the differences are only due to the remaining 0.1% of DNA. Only the identical twins share the same DNA and not everyone. Therefore, DNA is very personal and correctly called an *individual's code of life, instruction book of life, language of life, and blueprint of life.*

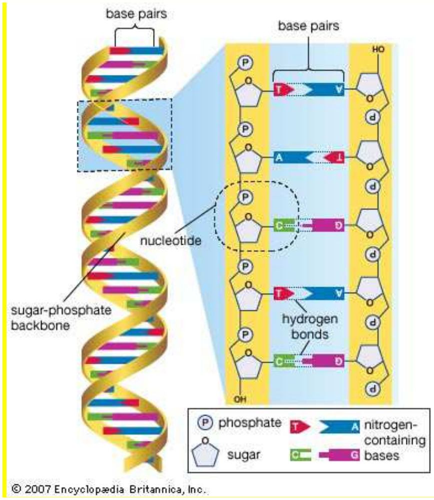

Figure 1: Schematic Diagram of DNA

DNA APPLICATIONS

Even though, DNA was discovered only six decades before, it has various applications in various biological areas like medicine, forensics, genetic engineering, bioinformatics, pharmaceutics, immigration, agriculture, nanotechnology, etc. Some of the DNA applications are reviewed below in this article.

Genetic Engineering

Genetic engineering is the area where the artificial manipulation, alteration, and recombination of DNA or other nucleic acid molecules are done in order to change an organism or the organism population as such. Literally, it can also be said as making new organisms. Genetic engineering is improvising the medicine, the future of health and is changing the future of crime scene analysis. Many developments have been made in medicine and science with the help of ongoing work with recombinant DNA technology. Recombinant DNA technology is a man-made method of inserting DNA from one organization into the DNA of another organism. The term used for producing medicinal products is Genetically Modified Organisms (GMOs). For example, bacteria produce insulin, interferon, human growth hormone, antibodies, vaccines and antibiotics. GMO is also used to produce agricultural crops that are commonly called, "Genetically Modified Organisms or Foods" – GMO/GMF. It is also used for producing transgenic plants like sweet corn, soybeans, alfalfa, canola, papaya, cotton, summer squash, sugar beets and also for increasing resistance against diseases, insects, herbicides, and drought. It is also necessary for increasing nutrition and nitrogen fixation in plants. It also produces genetically modified animals like dairy cows for milk augmentation and dog varieties for diverse morphological traits. It has its role in industries that help in cleaning oil spills in oceans.

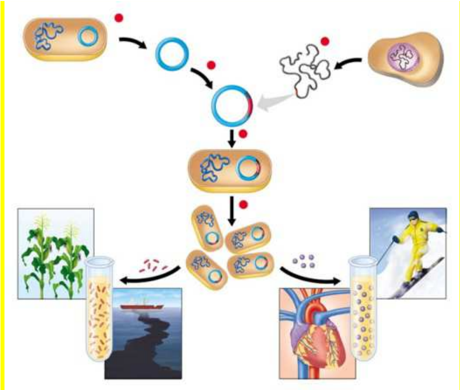

Figure 2: Diagram Depicting Use of DNA Recombinant Technique in Agriculture, Medicine, and Cleaning Oil Spills

DNA technology is also used to develop vaccines, drugs and for producing human hormones, proteins and antibiotics. Inserting a human DNA into an organism, turns that organism into a medicine producing factory, eg, insulin production by bacteria. The applications of DNA has also been found in genetically engineered pharmaceuticals, factors for hemophilia, human growth hormone (GH), erythropoietin (EPO) and for treating anemia. Interferon is to fight viral infections, personalized medicine (medicines tailored to individuals – future of medicine), and insulin for diabetics, TPA (tissue plasminogen activator) for dissolving blood clots, and adenosine deaminase (ADA) for the treatment of some forms of severe combined immunodeficiency (SCID).

One of the major medicinal applications of DNA is a personalized genetic medicine. Barack Obama, while introducing the bill, "Genomics and Personalized Medicine Act 2007" as a senator said, "we are now in the new era of life sciences, but in no area of research is the promise greater than in personalized medicine". The genome of a baby could be sequenced at birth revealing the susceptibility to particular diseases. In such cases, the baby could enjoy the benefits of made-to-order diagnostics drugs and tools throughout her lifetime. Recent studies show that majority of the genetic diseases are produced by the interplay of many genes, rather than a single gene, which arise due to both environmental and genetic causes. A recommendation has been given by the American Society of Clinical Oncology for genetic testing of personal cancer susceptibility. This could be a routine part clinical testing done by detecting mutations in BRCA1 and BRCA2 genes implicated in some ovarian and breast cancers.

Sex Identification

DNA analysis is also used for identifying the sex of an individual. The difference between the male and female is that the male possess Y chromosome. Thus, the DNA detection is specific to Y chromosomes and helps to distinguish male from female. To identify the sex of an unborn child, DNA tests are used. Identification of sex of a fetus is delayed until the anatomical differences have developed before the sex identification by scanning. But, under rare circumstances, an earlier identification is required. For example, a family could indicate that an unborn male child may suffer from an inherited disease and if the parents wish to decide about the continuation of pregnancy. Analysis of archaeological specimens is another application of DNA-based sex identification. It is responsible for many developments in this field. If the key bones like the skull or the pelvis remains intact, male and female skeletons could be distinguished. But with the fragmentary remains and that of young children, there will not be enough anatomical differences that are sex-specific and this will not help in confident identification. The archaeologists can identify the sex using DNA-based method, if the ancient DNA is preserved in the bones.

Pharmacogenetics or Pharmacogenomics

Pharmacogenomics is a new form of pharmacology in which, the DNA is used to develop and test drugs in order to study why some drugs work in some individuals and not in others, and why it is toxic to some patients and no to others. For instance, it finds its usage in determining the response of patients towards drugs during the treatment of cancer and tailor pharmaceutical administration. According to American Medical Association (AMA), pharmacogenomics is potential enough to provide tailored drugs therapy. This therapy is based on genetically determined difference in effectiveness and side effects which means more powerful medicines, better and safer drugs, and more accurate drug dosages. This will ultimately result in reduced drug responses, less time it takes to get a drug approved, fewer number of failed drug trials, reducedmedication time for patients, and reduced number of medications patients should find an effective therapy.

Forensics

Sir Alec Jeffrey, a British biologist developed DNA profiling in 1984. It was first used in forensic science in 1988 to convict Colin Pitchfork in England for Ender by murder case. It is a very useful forensic tool that helps in examining the DNA found in the crime scene. To identify and describe the DNA profile, the methods used are Restriction Fragment Length Polymorphism (RFLP) and Short Tandem Repeat Profiling (STR). DNA is taken from the tissues of semen, blood, saliva, skin and hair at the crime scene. These samples serve the purpose of identifying the matching DNA of an individual - *DNA profiling or the genetic fingerprinting.* Even though it is highly reliable, the identification becomes complicated if the DNA at the crime scene is contaminated with DNA from several other people. DNA databases are also used to identify, track, arrest, catalogue and prosecute the committers of crimes.

Bioinformatics

Bioinformatics is a field that helps in the management and interpretation of biological data. It can be said as a computer science application in the field of molecular biology, such as reactions inside the cell. The main objective of bioinformatics is to use genomic information to comprehend human diseases and also increases our understanding of the identification of new molecular targets for drug discovery. Its main uses are in prediction of gene expression, drug designing, and species evolution.

Archaeology and Anthropometry

DNA is also used to understand the human evolution, identify individuals, and trace migrations of people and to determine the origins of domestic animals and plants. The anthropological questions can be addressed by the analysis of DNA taken from archaeological specimens. This also helps in finding migratory patterns, DNA evolution, and tracking species evolution over the ages. Molecular anthropology is one of the fields of anthropology, which is used to define evolutionary connections between ancient and modern human populations and between contemporary species by using molecular analysis. Scientists can define the understanding of relationships between/ within populations, by examining the sequences of DNA in various populations. Molecular anthropology is very useful, in establishing the evolutionary tree of humans and other organisms like primates, including species like gorillas and· chimps.

Nanotechnology

DNA is used as a structural material more than as a biological information carrier. Productions of nanomechanical devices, that have algorithmic self-assembly have been established. It has a great potential in gene therapy, as the 3 dimensional nanostructures can hold to regulate protein-folding. This technology uses tiny molecules carrying the medication or corrective enzymes to identify and correct the defective gene. In gene therapy, DNA nanotubules are used, to substitute the viral DNA that is used as a vehicle for carrying the external gene to the targeted site called *transfection.* But there will be some side effects like tumor formation. These are small therapeutic agents, which can navigate to a specific target with their own power in the body without any side-effect. On reaching the target place, these machines act in many ways right from the delivery of medicinal pay load till providing real-time status on the fighting progress of disease. Once their mission is achieved, they biodegrade leaving minor or no trace at all. Getting these non devices to their target location in the body is one of the greatest challenges. Ultrasound waves and magnetic fields are used to direct them towards medicine-containing nano-bubbles that can erupt at the target site and force the medicine into it – these are the important factors for taking the nanodevices to their target sites. In animals, the magnetic approaches have shown potential in connecting the iron oxide nanoparticles to the individual stem cells and taking them to the broken bone sites. "Micro motors" or "Nanomeds" are the tiny molecular machines, which stay inside the body until the cell damage is detected resulting in the trigger of activity. These micro motors can resolve the problem of the requirement of external guidance for ultrasonic and magnetic guided devices for the transport of the therapeutic cargo. These micro motors depend on chemical reactions for propulsion like oxidation of glucose molecule for generating energy; even more favorable propositions are the naturally happening substances, such as stomach water and acid, occurring in large quantities in the body.

Immigration

Immigration testing is done to find a reliable solution and document a blood relationship in immigration cases. The immigration requirements could be satisfied by DNA testing. It is a very powerful tool, which helps to verify a biological relationship when no credible evidence is presented for immigration, eg., maternity, paternity, sibling ship, half-siblingship, etc. For this test, a buccal swab is used, in which the cheek is brushed with a cotton swab and the cells are gathered for testing. Buccal swabs are easier and non-invasive, which helps to gather and ship the samples easier than blood samples. The results yielded are reliable and accurate. This technique is used for parental testing and genetic fingerprinting for determining whether both the individuals have a biological parent-child relationship, acting as a genetic proof to find the biological relativity.

CONCLUSIONS

This article reviewed the nature of DNA, elucidation of its structural configuration, and exponential expansion in its practical applications. Having been discovered only in 1952 primarily for the academic interest, its applications have now extended to genetic engineering resulting in the production of new organisms or GMOSs, sex identification of new born before the development of sex organs, pharmacogenetics or pharmacogenomics wherein the DNA can be used to develop and test drugs instead of the animals and humans, forensics to identify criminals and crime scenes, bioinformatics entailing applications of computer technology to the management and interpretation of biological information, anthropology to understand the evolution of the modern humans, nanotechnology in which DNA can be used as structural material for the manufacture of minute devices that can reside inside the human body to monitor, diagnose and treat diseases and disorders, and immigration for determining the biological relationships among people to satisfy the immigration requirements. Several more DNA applications to the real-world biological problems are emerging at a pace never imagined at the discovery of the DNA.

REFERENCES

1. Shivanand, P. and Noopur, S. (2010). Recombinant DNA Technology: Applications in the field of biotechnology and crime sciences. http://www.globalresearchonline.net/volume1issue1/Article%20009.pdf
2. Dickenson, D. (2013). Personalize Genetic Medicine. In Krimsky, S & Gruber, J. (Eds), Biotechnology in Our Lives. Skyhouse Publishing.
3. Krimsky, S & Gruber, J. (2013). Biotechnology in our lives: What modern genetic can tell you?https://books.google.com/books?id=TeAeAwAAQBAJ&pg=PT3&lpg=PT3&dq=Krimsky+%26+Gruber,+2013&source=bl&ots=r58JtI8Nul&sig=lPONpBDNY-16ICKaqC5CUYqX48I&hl=en&sa=X&ved=0ahUKEwjtnKj75IvWAhUF7IMKHbxlBeY4ChDoAQglMAA#v=onepage&q=Krimsky%20%26%20Gruber%2C%202013&f=false
4. Simmons, D. (2008). Epigenetic influence and disease. Nature Education 1(1):6. http://www.nature.com/scitable/topicpage/epigenetic-influences-and-disease-895)
5. AMA (http://www.ama-assn.org/ama/pub/physician-resources/medical-science/genetics-molecular-medicine/current-topics/pharmacogenomics.page?)
6. Portman, J. (n.d.). Using DNA in Criminal Investigations and Cases. http://criminal.lawyers.com/criminal-law-basics/use-of-dna-in-criminal-investigations.html
7. Katara, P. (2013). Role of bioinformatics and pharmacogenomics in drug discovery and development process.https://link.springer.com/article/10.1007%2Fs13721-013-0039-5
8. Crawford, M. H and Beaty, K. G. (2013). DNA fingerprinting in anthropological genetics: past, present and future. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3831593/
9. Bajwa, M. (2016).Nanomedicine – The Futuristic Medicine.International Journal of General Medicine and Pharmacy (IJGMP) ISSN(P): 2319-3999; ISSN(E): 2319-4006 Vol. 6, Issue 1, Dec - Jan 2016; 1-8
10. Hockley, M. (n.d.). The future of nanodevices in medicine. http://www.britishsocietynanomedicine.org/assets/files/Matthew%20Hockley%20FINAL%20essay.pdf
11. Greenemeier, L. (2015). Nanomedicine in coming decades launches the nanobots!. Scientific American; April, 2015: 50-51.
12. Webmd. (n.d.). DNA Fingerprinting http://www.webmd.com/a-to-z-guides/dna-fingerprinting#1