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IB BIOLOGY HL
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October 24, 2010

DNA; Past, Present, and Future

DNA, or deoxyribonucleic acid, is a nucleic acid containing genetic information and instruction that is essential in the growth and operation of all living organisms (except certain viruses). Due the fact that DNA's main role is the long-term preservation of information, it is frequently compared to a set of blueprints; somewhat resembling a recipe or code. DNA is composed of segments called genes that contain the process directions needed to build other cellular components such as RNA and proteins. Segments aren't the only sequences that constitute DNA; others are used for structural purposes or regulation of the use of the stored information. DNA comprises of two long polymers called nucleotides, which consist of backbones constructed by sugars and phosphate groups held together by ester bonds. As the two strands run in opposite directions in an anti-parallel manner, they form a double helix. The four types of molecules attached to each sugar as called adenine, guanine, thymine, and cytosine. These bases create the sequences of information that are read by genetic code by a process called transcription; copying expanses of DNA into the RNA. Chromosomes are long, organized DNA structures which are duplicated during cell division; DNA replication. Although both eukaryotes and prokaryotes store DNA, eukaryotes do so in the nucleus (with the exception of mitochondria and chloroplasts which have their own DNA) and prokaryotes do so in the cytoplasm. Chromatin proteins in the chromosomes compress and organize DNA, thus maneuvering the interactions between DNA and other proteins.

DNA was discovered for the first time in 1869, by Swiss physician Friedrich Miescher. He discovered a microscopic substance in the cellular nuclei of the pus of discarded surgical bandages, which he named "nuclein". A short while later, in 1919, Phoebus Levene discovered the general structure of DNA; the sugar and phosphate base. Although he thought that DNA consisted of a string of nucleotides through the phosphate groups, he was incorrect in suggesting that the chain was short and the bases repetitive in a fixed manner. This error was only rectified in 1937, when William Astbury brought forth the first X-ray diffraction patterns showing DNA's regular structure. Additionally, in 1928:

> Frederick Griffith discovered that traits of the "smooth" form of the Pneumococcus could be transferred to the "rough" form of the same bacteria by mixing killed "smooth" bacteria with the live "rough" form. This system provided the first clear suggestion that DNA carries genetic information – the Avery-MacLeod-McCarty experiment – when Oswald Avery, along with coworkers Colin MacLeod and Maclyn McCarty, identified DNA as the transforming principle in 1943. DNA's role in heredity was confirmed in 1952, when Alfred Hershey and Martha Chase in the Hershey-Chase experiment showed that DNA is the genetic material of the T2 phage.[1]

As a phage is a virus that uses a bacterium's machinery and energy to produce more phage until the bacterium is destroyed and phage is released to invade surrounding bacteria, it is obvious that it uses self-replication, and thus, passes on traits. If DNA is contained in the genetic material of phage, it is definitely a hereditary tool. Hershey and Chase's findings was the first major turning point in the history of DNA. A second one was when, in 1953, James Watson and Francis Crick suggested the now-used double-helix model of DNA structure. Their proposal was based on an X-ray diffraction image taken by Rosalind Franklin in May 1952, and on raw information about DNA bases being paired from Erwin Chargaff, whose rules played a significant role in the establishment of double-helix configuration. Furthermore, Crick articulated the relationship between DNA, RNA, and proteins in 1957, thus laying out the "Central Dogma of molecular biology". Finally, in 1958, the Meselson-Stahl experiment confirmed DNA's replication mechanisms, and additional work by Crick and his coworkers illustrated that genetic code was a series of non-overlapping triplets of bases, also known as codons. Using this work, Har Govind Khorana, Robert W. Holley, and Marshall Nirenburg deciphered the genetic code. To sum it up, Crick and Watson's work was the final catalyst which represented the birth of molecular biology, and introduced versatile and useful usages of DNA.

Without the significant works of Miescher, Astbury, Hershey, Chase, Avery, Macleod, McCarty, Crick, Watson, Khorana, Holley, and Nirenburg, DNA could never be the powerful tool it is today. These people led the way to modern DNA analysis. As DNA was identified as a container of genetic information, nowadays, it is used to identify, screen, detect, develop, prevent, and treat. In short, it has furthered science

[1] (Stint)

significantly. In today's day and age, DNA analysis and the information gathered from it is routinely used in forensic investigations, the field of biosecurity, postal services, environment and food testing, biochemical engineering, the study of climate change, and medicine. Criminals are linked to crime scenes via DNA analysis, and so are paternities determined, and victims of mass disasters such as 9/11 and hurricanes identified. Genetic analysis, which is only possible because the structure of DNA and the knowledge that DNA contains genetic information is known, allows public health agencies to identify infectious diseases in a quick manner, thus monitoring the threats. The U.S. postal service frequently uses DNA analysis to examine packages for forms of bioterrorism (e.g. anthrax). On a similar note, the presence of food and health threatening microorganisms such as E. coli and genetically modified organisms can be detected via DNA analysis. It is also used to predict and better the future of the Earth and its climate, and human healthcare:

> Information gleaned from the characterization of complete microbial genomes is now being applied to develop alternative sources of energy and understand biological carbon cycling as it relates to global climate change. In the emerging era of personalized medicine, DNA analysis is already helping researchers and physicians to better understand disease predisposition, subtypes, and response to treatment. Several targeted medicines are already available, which are designed to work for patient exhibiting a specific DNA profile. 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. An additional application of DNA fingerprint technology is the diagnosis of inherited disorders in adults, children, and unborn babies. The technology is so powerful that, for example, even the blood-stained clothing of Abraham Lincoln could be analyzed for evidence of a genetic disorder called Marfan's Syndrome.[2]

As mentioned in this passage, DNA fingerprinting is the most utile advances in microbiological technology today. It is a laboratory procedure that uses DNA-modifying enzymes, such as nucleases and ligases. Nucleases are enzymes that cut DNA strands by catalyzing the hydrolysis of the phosphate-ester bonds. The most frequently used

[2] (Betsch)

nucleases are the restriction endonucleases, which cut DNA at specific sequences. Naturally, these enzymes prevent phage infection in bacteria by digesting the phage upon entry. In science, they are used in molecular cloning and DNA fingerprinting. Ligases carry out the opposite functions; they reform cut or broken DNA strands. They are used to join together short segments of DNA to replicate a complete copy in DNA repair and genetic recombination. DNA fingerprinting requires five steps:

1. Isolating the DNA; only a small amount of tissue is needed.
2. Cutting, sizing, and sorting the DNA via nucleases (EcoR1); the DNA pieces are then sorted according to size by a sieving technique called electrophoresis and passed through agarose (seaweed gel).
3. Transferring the DNA to nylon; the nylon sheet is placed on the gel and soaked overnight.
4. Probing; placing radioactive probes to the nylon sheet makes a pattern which is the DNA fingerprint; each probe usually sticks in only a couple of specific places on the nylon sheet.
5. DNA Fingerprint; it is built with approximately 5 to 10 probes at the same time; looks like bar codes.

This process of DNA fingerprinting is globally used to diagnose inherited syndromes and disorders in both fetuses and newborn babies such as cystic fibrosis, hemophilia, Huntington's disease, Alzheimer's, sickle cell anemia, etc. When such disorders are detected early, it proves beneficial for both the hospital staff and the family of the diseased:

> 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. 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 DNA patterns associated with the

> disease in question. This work is a necessary first step in designing an eventual genetic cure for these disorders.[3]

This passage elucidates that DNA fingerprinting plays a vital role in today's society, where the necessity of population remains a question. Additionally, DNA fingerprinting is used in the justice system, as FBI and police labs use DNA fingerprints to determine whether suspects are linked to the biological evidence (hair, blood, semen, clothing items) found at a crime scene. Also, DNA fingerprints are used as perfectly accurate pieces of evidence to establish blood relations in custody and child support cases. Finally, the US armed services have just started a program to collect DNA fingerprints from all their personnel for later use in the case of casualties or missing persons; a far better identification source that dog tags or dental records. To sum it up, DNA has furthered and better science to a great extent in today's society yet it could not have done so without the foundation of discovery that previous scientists such as Crick and Watson left behind.

Since DNA can be used to such an extent in the present, it is safe to deduce that it will play an even more significant role in the future. According to Mark Stevenson, executive vice-president for Applied Biosystems:

> Science is entering a new era, in which recent technological developments have created 'power tools' that will enable even more rapid progress in delivering on the promise of genomics to help protect and preserve human health and safety, as well as our environment. The promise of next-generation DNA sequencing technology is to broaden the applications of genomic information in medical research and health care, reduce the cost of sequencing without sacrificing quality, and enable discoveries that are expected to revolutionize the practice of medicine.[4]

In other words, new tools that use DNA will allow further advances in connecting genes and genetic variations with the appropriate diseases and responses to treatment. Thus, new therapies and the hope for cures will develop by using information from the genetic bases of disorders such as cancer, Alzheimer's, and diabetes. A new DNA test uses saliva to determine whether a person is liable to develop a dangerous disease; this

[3] (Reno, Marcus and Leary)

[4] (Reno, Marcus and Leary)

can evolve into a speedy and economic test determining whether a person will inherit a hereditary illness. If all goes according to plan, one drop of saliva will be enough to enable medical experts to "pinpoint variations in patients' genetic code is a test being formulated by scientists at Edinburgh University. Tiny differences or omissions at critical points in the DNA chain can determine whether a person is healthy, prone to disease, or has a life-threatening condition such as cystic fibrosis". According to Professors Juan Diaz and Mark Bradley of Edinburgh University:

> This technology offers a speedy, cost-efficient alternative to existing methods of DNA analysis. The market for DNA testing is quickly expanding as it becomes more affordable. Our method could help reach the goal of complete genome (order of genes in a set of chromosomes) analysis in a few hours for less than $1,000 (£637). We plan to test the technology further, extend our collaborations with leading researchers and companies in the DNA sequencing field, and establish our first commercial operations within the next six months.[5]

This quote proves that DNA will indeed come to better uses in the immediate future as it will aid the prevention of hereditary or other dangerous disorders/diseases. In my opinion, even though one's vision clouds when predicting the further future, it is safe to say that DNA will still come to good use, one that benefits the justice, social, and medical systems. In the long run, the usage of DNA in technology will benefit society at large. For example, today, DNA is used to stem the tide of human trafficking, as on the 26th and 27th of October, 2009, experts in genetic identification from Brazil, China, Guatemala, India, Indonesia, Mexico, Nepal, the Philippines, Spain, Sri Lanka, Thailand, the UAE, the US, and the UNODC met in Granada, Spain to hold the DNA – Prokids Scientific Group Meeting, an organization that has agreed to a series of commitments to foster international partnerships for joint action against human trafficking. They work towards obtaining DNA samples from kids found outside their families; victims of prostitution, forced labor, militants activities, and illegal adoption, and creating DNA profiles to store in an international database where they can be searched against the DNA profiles provided by families who have their children kidnapped or lost. In the long run, this movement will help reduce the global crime of human trafficking, and thus improve safety. Therefore, it can be concluded that DNA is already used to work

[5] (Reno, Marcus and Leary)

towards a better future, and will come to play even more beneficial roles in the actual future.

In conclusion, DNA has a variety of different uses in the present, and will have great uses in the future. However, none of this could have been possible without the various discoveries made in the past. If DNA's role in heredity wasn't discovered, it would be worthless to us today. Although we, in a very human manner, assume that all that needs to be discovered about DNA has been discovered, it may not be so and its uses may change radically in the future. However, we know for certain that DNA is not potentially harmful in any way as it occurs naturally. All in all, it has furthered science a lot, and will keep doing so in the future.

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