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Date

Deciphering Life Code: James Watson and Francis Crick’s Groundbreaking Discovery and Its Implications

Watson and Crick’s discovery of the structure of Deoxyribose Nucleic Acid (DNA) is one of the most pivotal milestones in scientific history not only because it resolved a century-long scientific inquiry, but it also provided the foundation for scientists to make scientific advancements that led to even more turning points in modern history.

Prior to Watson and Crick’s work on their research paper, understanding the structure of DNA was the key debate surrounding the understanding of genetics. Decades before Watson and Crick made their discovery, scientists such as Charles Darwin and Gregor Mendel formed the basis of genetics through proposing various theories. However, they have ultimately failed to figure out the units that transmitted genetic materials from one generation to the next generation. To discover these unknown units, scientists conducted various research for the next few decades and found two possible candidates that could be the units that transmit genetic materials: DNA and protein. Until Watson and Crick’s discovery, many firmly believed that the proteins were the carriers of genetic information because they are versatile molecules located in the cytoplasm that catalyze chemical reactions and provide structural support. However, this widely-held belief was soon challenged by some prominent scientists at that time through the Avery-MacLeod-McCarty Experiment (1944).

In 1944, Oswald T. Avery, Colin M. MacLeod, and Maclyn McCarty conducted an experiment that suggested that DNA might be the hereditary material that caused bacterial transformation instead of protein. In “Studies on the Chemical Nature of the Substance Inducing Transformation of Pneumococcal Types”*,* Avery and his colleagues stated that “the evidence presented supports the belief that a nucleic acid of the deoxyribose type is the fundamental unit of the transforming principle of Pneumococcus Type III” (Avery et al 20). Although several flaws existed in his research, such as the fact that his DNA extracts contained fragments of protein materials, his experimental results had a significant implication: his result prompted many scientists like Watson and Crick to reconsider the role that DNA plays in the body cells.

As a result, Watson and Crick started their research to prove that DNA carries the information. During the process, two scientists named Rosalind Franklin and Maurice Wilkins were helpful in a sense that they provided X-ray data that could be used by Watson and Crick to build various models of structure of DNA since Franklin and Wilkins acquired the data through the usage of X-ray crystallography, which can determine the positions of every single atom relative to every atom. They both worked at London College and facilitated Watson and Crick’s research process because they knew that they were working toward shared goals. Specifically, Franklin’s X-ray crystallography was crucial to the discovery of DNA structure since her X-ray data suggested that the phosphates were located on the outer area of the DNA structure, which Watson and Crick failed to realize prior to acquiring her data. J.D Bernal, one of the most famous Irish scientists who pioneered the use of X-ray crystallography, once described Franklin’s photographs as “the most beautiful X-ray photographs of any substance ever taken” (Bernal).

Despite the data provided by Franklin and Wilkins, Watson and Crick struggled to create an accurate model of DNA. For instance, Crick created a model in their laboratory that had a helix with three sugar phosphate chains on the inside and the bases sticking out. Although he deemed that his model was identical to the actual DNA structure, it was quickly dismissed by Franklin. Watson and Crick went through this process multiple times. Then one day, Wilkins brought a picture from the Franklin’s drawer that ultimately resolved the mystery of the structure of DNA: Franklin’s photo 51 (BioInteractive).

After recognizing the diffraction pattern depicted in Franklin’s photo 51, Watson realized that the DNA is a double helix. The discovery of double helix structure proves that the DNA carries genetic information because having this structure allows each strand to serve as a template for the new strand synthesis and that this complementary structure allows genetic information to be replicated and passed on during cell division. To publicize this groundbreaking discovery, Watson and Crick published a paper called “A Structure for Deoxyribose Nucleic Acid” on April 25, 1953. In the paper, they said, “the specific pairing we have postulated immediately suggested possible copying mechanism for the genetic material,” officially indicating a turning point in scientific history that resolved the ongoing controversy about the DNA structure and protein synthesis (Watson and Crick 77).

Their finding had significant short term and long-term implications since it created paths for researchers in the field to have a better understanding of DNA replication. The discovery of the double helix structure not only corroborated Chargaff’s rule, which states that the number of purine bases and pyrimidine bases are equal, but also revealed that nitrogenous bases have complementary structure: adenine pairs with thymine while guanine pairs with cytosine. According to Lawrence Brody, this pairing hinted at the method in which genetic information could be replicated and passed on during cell division since each strand can serve as a template for the new strand synthesis. Realizing this, Watson and Crick published an article about the DNA replication mechanism in 1953 along with their famous paper about the structure of DNA.

Although their paper was the first to introduce a plausible DNA replication method, the paper had flaws. In 1954, Max Delbrück published “On the Replication of Deoxyribonucleic Acid (DNA)” in *PNAS*, which criticized Watson and Crick’s idea that the DNA strands untwist completely and separate before replication, suggesting that ‘dispersive replication’, a method in which the separation and replication occurs simultaneously, is more plausible. He dismissed their idea, “because it rejoins chains with opposite polarity, which is chemically not permissible” (Delbrück 785).

Even though Watson and Crick’s paper about DNA replication was not widely upheld, they ultimately created a significant turning point in the history of genetics through forming the basis for future research. Gene sequencing, a technique to determine the order of nucleotides, became especially important following the discovery of DNA structure because scientists became able to identify the information carried in any portion of DNA, allowing them to obtain accurate data to analyze for research on certain diseases. However, the sequencing was not an easy task. In “The sequence of sequencers: The history of sequencing DNA” published in *PubMed*, the authors say “DNA molecules were much longer and made of fewer units that were more similar to one another, making it harder to distinguish between them” (Heather). While many scientists were struggling to find the method for gene sequencing, scientist Frederick Sanger developed a rapid sequencing technique called Chain Termination that amplified the DNA fragment. As this technology became more efficient over time, researchers utilized this to facilitate a major project that resulted in another turning points in history of the field of science: the Human Genome Project (HGP) and the creation of Genetic Map.

The goal of the HGP was to analyze all the possible genome sequences in humans and form a better understanding of the genes. Thanks to the efficient work done by affiliated organizations and researchers, the project ended 2 years prior to the expected end year. Moreover, researchers from various countries efficiently recruited volunteers and applied the ‘chain termination’ technique, ultimately sequencing approximately “92% of the human genome and less than 400 gaps” (National Human Genome Research Institute). After this project was officially ended, many acclaimed the remarkable achievement accomplished through this project. For instance, President Bill Clinton once said, “without a doubt, this [Genetic Map] is the most important, most wondrous map ever produced by humankind” (“June 2000 White House Event”). Later in his speech, he even credited Watson’s contribution to the creation of Genetic Map and said, “Dr. Watson, the way you announced your discovery in the journal Nature, was one of the great understatements of all time. This structure has novel features, which are of considerable biological interest” (“June 2000 White House Event”). The reason why Clinton acclaimed Watson’s discovery of the DNA structure is simple: HGP was able to be conducted in a setting where the understanding of the DNA structure led to the development of gene sequencing techniques and other computing systems to facilitate the research process. The establishment of Genetic Map in HGP marks another turning point given that it essentially contains the complete set of genomic sequences that can help researchers acquire better understanding of the functions of genes and their variations. In other words, this project by itself created paths for the advancement in Biotechnology and Genetic Engineering.

Certainly, genetic engineering has transformed the current paradigm of science thanks to its capabilities. With the creation of Genetic Map and a better understanding of DNA, scientists are improving gene modification techniques such as CRISPR (Clustered Regularly Interspaced Short Palindromic Repeat) in the medical field since “it has potential for correction of human genet diseases” (Yin, Xue, Chen). Moreover, scientists have developed GMOs (Genetically Modified Organisms)—especially GMO crops in agricultural industry—since “GMO crops are anticipated by many to play a significant role in the arsenal of technologies that will be required to support global food security and agricultural sustainability in the next 35 years as the population moves toward its steady state of 9 to 11 billion people”(Agricultural Biotechnology: Economics, Environment, Ethics, and the Future). Not only did gene modification become a pragmatic tool for scientists to treat diseases plaguing millions of people, but also to spur economic growth and enhance individuals’ lifestyle. However, some object to the practicality and morality of genetic modification through illustrating the ethical implications of genetic engineering and its unintended consequences when misused.

When evaluating the effects of GMOs or genetic modification, transhumanism—a belief that genetic engineering should be used to modify and better the mental and physical functions of humankind—comes to the spotlight. Transhumanism represents the rapid transformation that the world has experienced and challenges humanity to answer the moral and philosophical questions that arise in the process of creating more turning points in the history of science. One of the most famous examples that represents transhumanism is the creation of designer babies, which are babies whose genetic information is artificially altered or chosen by their parents. In the process of making designer babies, PDG (preimplantation genetic diagnosis) is used to screen for diseases and help parents choose embryos with the physical traits that they wish their children to have. Critics who denounce the idea of having designer babies claim that this type of genetic engineering—genetic modification used besides the disease treatment purposes will fuel the social inequality and even introduce a new form of eugenics. As the idea of creating designer babies gain its popularity, social inequity may arise as rich parents would afford more designer babies while middle class and people living under the poverty line will continue to fail to manage the expenses of having designer babies. This new inequality would exacerbate the existing social tension and prompt the rich to gain unfair advantages in societies that operate under meritocracy. Likewise, many fear that this engineering will introduce a new type of eugenics, invoking the idea of Social Darwinism and bringing back the past efforts to eliminate “socially and biologically inferior” races and breed “racially superior” human beings.

Since the late 20th century, various global and domestic organizations have worked to devise measures to tackle the negative implications of genetic modification. Government agencies such as the World Health Organization (WHO) and the Food Drug and Administration (FDA) have established guidelines and regulations regarding the advancement of genome editing. Believing that “the full impact [of genome editing] will only be realized if we deploy it for the benefit of all people,” WHO Director-General announced their “recommendations on the governance and oversight of human genome editing in nine discrete areas”. While the WHO laid out a standard that countries may adopt to ethically conduct human genome editing, the FDA specifically imposed sets of regulations to ensure the right usage of GMOs. Collaborating with the U.S. Environmental Protection Agency and the U.S. Department of Agriculture, the FDA created the Coordinated Framework for the Regulation of Biotechnology and created various safety standards to prevent GMOs from causing harms to the consumers and the environment.

Likewise, in 1990, a decade before the complete sequencing of genomes, NHGRI created the Ethical, Legal, and Social Implications (ELSI) Research Program to address the unintended consequences of genetic engineering. The US Congress required that “NHGRI dedicated at least 5% of its research budget to studying the ethical, legal and social implications of genomic advances.” To this end, ELSI researchers took educational initiatives and were involved in creating policies to tackle ethical issues such as genetic stigmatization, eugenics, and privacy concerns. For instance, one of its major achievements is its contribution to the Genetic Information Nondiscrimination Act (GINA) in the United States. In terms of international effort, in 2015, International Summit on Human Gene Editing was held in Washington DC., where approximately 500 people worldwide convened to deliberate on the ethical issues raised through the use of genetic engineering. In this summit, notably, Indira Nath, a researcher associated with All India Institute of Medical Sciences, made an important note by saying that “with national policies becoming rapidly transnational, one would say that governance is no longer just local, but is becoming a network of nations working together.” As Nath claimed, realizing the necessity of transnational interdisciplinary cooperation, international agencies and apparatuses have made collective efforts to set the right path pertaining to the advancement of genetic engineering. Although universal regulations have not been established and imposed yet, world leaders realized the ethical implications of genetic editing and have engaged in public-dialogue for the past decades. They are working to develop the universal framework that countries and individuals must abide by to address the problems, getting one step closer to creating another turning point in history that will determine the outlook of biotechnology and humanity as a whole.

A turning point in history is like a piece of domino block; a turning point leads to more turning points subsequently. Among many, Crick and Watson’s discovery of the structure of DNA is viewed as one of the most influential turning points in the history of genetics due to its short-term and long-term implications. Some of its consequences—advancement in molecular biology, genetics, and agriculture—have made positive contributions to our society. However, the others led to unintended consequences that raised international concerns. While it is true that negative ethical and moral implications exist, today’s society has measures to tackle those problems and create a path in which the advancement in genetics will do more good than harm to the international community. Watson and Crick’s Discovery is such an iconic achievement, and it will forever serve as a manifestation of perseverance and curiosity.

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