


The Genetic Blueprint: Biology Students Fundamental Learning of DNA Structure and Function

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ARTICLE INFO	ABSTRACT
<p>Keywords: <i>Structure of DNA, DNA replication, Gene expression, DNA mutations and DNA applications.</i></p> <p><i>Received: 02, Mar. 2026</i> <i>Revised: 09, April 2026</i> <i>Accepted: 17, April 2026</i></p> <p>©2026 Author(s): This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International</p> 	<p><i>This study focused on Genetic Blueprint: Biology students' fundamental learning of DNA structure and function. Understanding DNA structure and function by biology students offers them a comprehensive exploration of DNA's fundamental roles in biology. This paper begins by detailing the intricate double-helical structure of DNA, emphasizing its components: the sugar-phosphate backbone and nitrogenous bases. The study proceeds to elucidate the process of DNA replication, highlighting the mechanisms ensuring accurate copying and transmission of genetic information during cell division. Subsequently, the study examines gene expression, detailing how DNA sequences are transcribed into messenger RNA and translated into proteins, which perform essential cellular functions. The discussion then shifts to DNA mutations, categorizing them into point mutations, insertions, and deletions, and illustrating how these changes can affect gene and protein functionality. Lastly, the study addresses the practical applications of understanding DNA, including advancements in biotechnology, such as gene editing and cloning, as well as the vital role of DNA analysis in forensics and personalized medicine. By interconnecting these concepts, the study emphasizes the significance of DNA as a blueprint for life, revealing how its study is pivotal to advancing science, health, and technology. Ultimately, this study serves as an essential resource for biology students seeking to understand the complexities of genetic information and its profound implications in various fields.</i></p>

Introduction

Deoxyribonucleic acid order wise known as DNA is a molecule that carries the genetic instructions for the growth, development, functioning, and reproduction of all living organisms and many viruses. Its structure consists of two long strands forming a double helix, comprised of nucleotides that include a phosphate group, a sugar (deoxyribose), and nitrogenous bases (adenine, thymine, cytosine, and guanine). The sequence of these bases encodes genetic information, which is crucial for the synthesis of proteins through processes like transcription and translation which has so many significance in biology (Watson & Crick, 1953; Alberts et al., 2015).

The significance of DNA in biology extends to various fields, including genetics, molecular biology, and biotechnology. It plays a central role in inheritance, serving as the template for replication during cell division, ensuring genetic continuity across generations. Additionally, advances in DNA technology, such as CRISPR and genomic sequencing, have profound implications for medicine, agriculture, and forensic science, enabling targeted therapies, enhanced crop traits, and criminal investigations (Doudna & Charpentier, 2014; Rees et al., 2019). This study x rayed the structure of DNA, DNA replication, gene expression, DNA mutations and DNA applications of understanding.

Structure of DNA

DNA (deoxyribonucleic acid) has a distinctive double helical structure, first described by James Watson and Francis Crick in 1953. Each DNA molecule consists of two long strands composed of nucleotide units, which are the building blocks of DNA. Each nucleotide includes a phosphate group, a deoxyribose sugar, and one of four nitrogenous bases: adenine (A), thymine (T), cytosine (C), or guanine (G) (Peter, 2025).

The strands run antiparallel to each other, meaning they orient in opposite directions. The nitrogenous bases pair specifically: adenine pairs with thymine (A-T) through two hydrogen bonds, while cytosine pairs with guanine (C-G) through three hydrogen bonds, contributing to the molecule's stability. The sequence of these bases encodes genetic information and plays a critical role in protein synthesis. The sugar-phosphate backbone and the complementary base pairing are essential features that enable DNA replication and transmission of genetic information across generations.

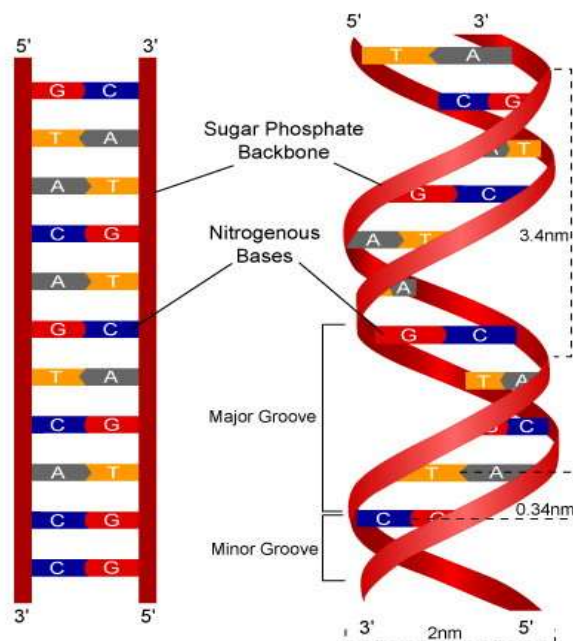


Figure 1: DNA structure

DNA Replication

DNA replication is a vital biological process in which a cell duplicates its DNA, ensuring that genetic information is passed accurately to daughter cells during cell division. This process occurs during the S phase of the cell cycle and involves several key steps and enzymes (Zhang et al., 2025).

The replication begins at specific locations called origins of replication, where the double helix unwinds, facilitated by the enzyme helicase. This unwinding creates two single strands of DNA that serve as templates for the new strands. Single-strand binding proteins stabilize these unwound strands, preventing them from re-annealing known DNA polymerase.

DNA polymerase, the primary enzyme involved in replication, synthesizes new DNA strands by adding complementary nucleotides to the template strands. It can only add nucleotides to the 3' end of a growing strand, therefore, replication occurs in a 5' to 3' direction. As a result, one of the new strands, known as the leading strand, is synthesized continuously, while the other strand, called the lagging strand, is synthesized in short fragments known as Okazaki fragments (Zhang et al., 2025; Alberts et al., 2015). Once the new strands are formed, the enzyme ligase connects the Okazaki fragments, completing the replication. The end result is two identical DNA molecules, each comprising one original and one newly synthesized strand, ensuring the accurate transmission of genetic information during cell division (Alberts et al., 2015).

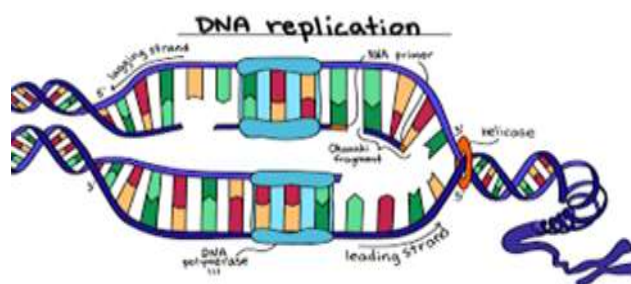


Figure 2: DNA Replication

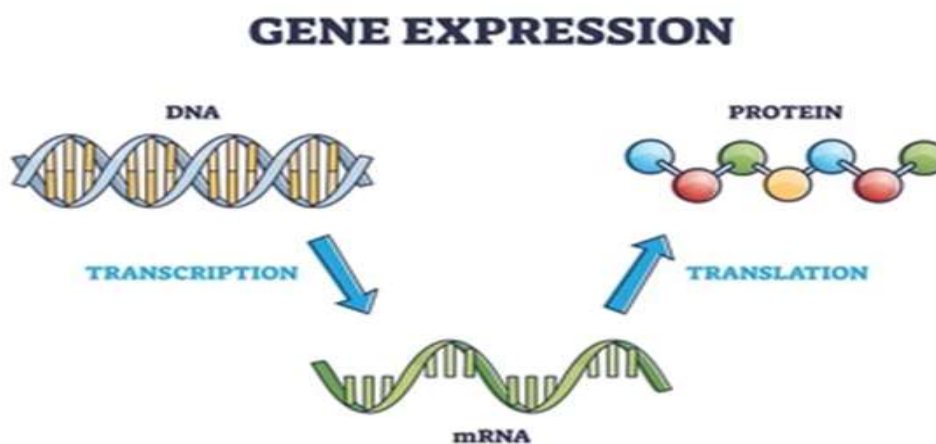
Gene Expression

Another concept in consideration in this study is gene expression. Gene expression is the biological process through which genetic information encoded in DNA is converted into functional products, typically proteins that perform various roles in the cell. This complex process includes two primary stages: transcription and translation (Zhang et al., 2025).

While transcription is the first step, where a specific segment of DNA is copied into messenger RNA (mRNA). This process occurs in the nucleus of eukaryotic cells, involving enzymes such as RNA polymerase. The DNA double helix unwinds, and RNA polymerase synthesizes a single-stranded mRNA molecule complementary to the DNA template strand. Specific sequences in the DNA known as promoters and enhancers play crucial roles in regulating the initiation of transcription. After transcription, the mRNA undergoes several modifications including capping, polyadenylation, and splicing, which enhance its stability and facilitate its export from the nucleus to the cytoplasm (Zhang et al., 2025).

Translation is the second stage, where the mRNA is translated into a protein at the ribosome. Transfer RNA (tRNA) molecules transport specific amino acids to the ribosome, where the mRNA sequence is decoded in sets of three nucleotides called codons. Each codon corresponds to a specific amino acid, and the ribosome assembles these amino acids into a polypeptide chain based on the mRNA sequence.

This is to say that gene expression is tightly regulated, with factors such as transcription factors and environmental signals influencing whether a gene is expressed. This regulation allows cells to respond to internal and external stimuli, ensuring proper function and adaptation in various contexts, such as development, differentiation, and response to stress (Xue et al., 2025).



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Figure 3: Gene Expression

DNA Mutations

Xue et. al. (2025) averred that DNA mutations are changes in the sequence of nucleotides in a DNA molecule. According to the authors these alterations can occur due to various factors, including environmental influences and errors during DNA replication. More so, mutations can significantly impact gene function and the resulting proteins, leading to various biological effects, ranging from neutral to detrimental or even beneficial. Types of mutation includes point mutations, insertions and deletions.

1. **Point Mutations:** These involve a change in a single nucleotide base pair. Point mutations can be classified into three categories:
 - **Silent Mutations:** These do not change the amino acid sequence of the protein because of the redundancy in the genetic code.
 - **Missense Mutations:** These result in the substitution of one amino acid for another in the protein sequence, which can alter protein function, stability, or activity.
 - **Nonsense Mutations:** These create a premature stop codon, leading to a truncated protein that is often nonfunctional.
2. **Insertions:** This type of mutation involves the addition of one or more nucleotide pairs into the DNA sequence. Insertions can disrupt the reading frame of the gene (frame shift mutations), altering the downstream amino acid sequence and potentially resulting in a nonfunctional protein.
3. **Deletions:** Deletions involve the loss of one or more nucleotide pairs from the DNA sequence and can also cause frame shift mutations. Like insertions, deletions can drastically change the protein produced.

Effects of gene mutation on genes and proteins, mutations can have various effects on genes and proteins. Some mutations may have no effect, while others can lead to genetic disorders, as seen in conditions like sickle cell anemia (caused by a missense mutation). Other mutations may contribute to beneficial adaptations in certain environments, illustrating the diverse outcomes of genetic variation. Overall, mutations play a crucial role in evolution by introducing diversity in genetic material (Wang et al., 2025).

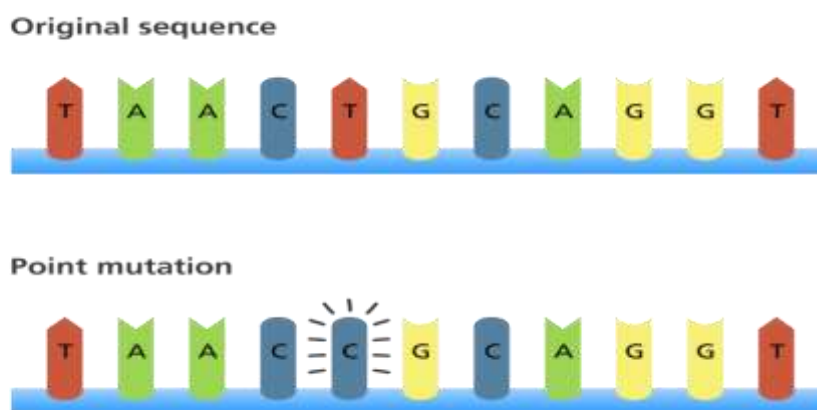


Figure 4: DNA Mutations

Applications of DNA Understanding

Understanding DNA has revolutionized biotechnology, forensics, and medicine, leading to groundbreaking applications that enhance our capabilities in these fields. In biotechnology, one of the most significant advancements is gene editing, particularly through technologies like CRISPR-Cas9. This method allows for precise alterations in the DNA of organisms, enabling targeted modifications that can correct genetic defects, improve crop resistance, and enhance traits in animals (Doudna & Charpentier, 2014). Additionally, cloning techniques, such as somatic cell nuclear

transfer, have led to the development of genetically identical organisms, which have applications in agricultural enhancement and stem cell research, providing insights into developmental biology and potential treatments for diseases (Kay et al., 2016).

In forensic science, DNA profiling has become a cornerstone for identifying individuals involved in criminal cases. By analyzing specific regions of an individual's DNA, forensic experts can establish genetic relationships and match biological evidence to suspects with high accuracy. This technique has significantly improved the reliability of evidence in court and helped exonerate wrongfully convicted individuals (Durga Prasad et al., 2024).

Furthermore, understanding of DNA plays a crucial role in personalized medicine. Genetic testing can identify predispositions to certain diseases, allowing for proactive measures or tailored therapies. Gene therapy, which involves correcting defective genes responsible for disease onset, holds promise for treating genetic disorders such as cystic fibrosis and muscular dystrophy (Kay et al., 2016; Bates et al., 1977). Overall, the insights gained from DNA research continue to drive innovation across various fields, enhancing our ability to solve complex biological problems and improve human health (Goodfellow et al., 1994; Durga Prasad et al., 2024).

Conclusion

In conclusion, the genetic blueprint: Biology students' fundamental learning of DNA structure and function highlights the intricate connection between DNA's structure, its vital roles in biological processes and how biology students can learn it through its applications. By examining DNA replication, gene expression, and the impacts of mutations, biology students gain insight into how genetic information is preserved, transmitted, and expressed. The applications of this understanding in biotechnology, forensics, and medicine underscore the transformative potential of DNA research in addressing real-world challenges, from developing innovative therapies to solving criminal cases. As we continue to unravel the complexities of DNA, its significance in shaping life and advancing science becomes increasingly evident, paving the way for future discoveries and applications that will enhance biology students understanding of genetics and its impact on society

REFERENCES

- Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., & Walter, P. (2015). *Molecular Biology of the Cell*. Garland Science.
- Bates, R. H. T., Lewitt, R. M., Rowe, C. H., Day, J. P., & Rodley, G. A. (1977). On the structure of DNA. *Journal of the Royal Society of New Zealand*, 7(3), 273–301. <https://doi.org/10.1080/03036758.1977.10419429>
- Doudna, J. A., & Charpentier, E. (2014). *The new frontier of genome engineering with CRISPR-Cas9*. Science.
- Doudna, J. A., & Charpentier, E. (2014). *The new frontier of genome engineering with CRISPR-Cas9*. Science.
- Durga Prasad, K., Prasad, B. S. R. V., & De, K. (2024). Importance of pesticide and additional food in pest-predator system: a theoretical study*. *Journal of Biological Dynamics*, 19(1). <https://doi.org/10.1080/17513758.2024.2444263>
- Goodfellow, J. M., Cruzeiro-Hansson, L., de Souza, O. N., Parker, K., Sayle, T., & Umrana, Y. (1994). DNA Structure, Hydration and Dynamics. *International Journal of Radiation Biology*, 66(5), 471–478. <https://doi.org/10.1080/09553009414551481>
- Kay, M. A., et al. (2016). *Adeno-associated virus vectors for gene therapy*. Nature.
- Peter, O. J. (2025). Modelling measles transmission dynamics and the impact of control strategies on outbreak Management. *Journal of Biological Dynamics*, 19(1). <https://doi.org/10.1080/17513758.2025.2479448>
- Rees, H. A., et al. (2019). *Base editing: precision chemistry on the genome and transcriptome of a*

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- living cell*. Nature Reviews Molecular Cell Biology.
- Wang, W., Sawleshwarkar, S., & Piraveenan, M. (2025). Computational approaches of modelling human papillomavirus transmission and prevention strategies: a systematic review. *Journal of Biological Dynamics*, 19(1). <https://doi.org/10.1080/17513758.2024.2436376>
- Watson, J. D., & Crick, F. H. C. (1953). *Molecular structure of nucleic acids: A structure for deoxyribose nucleic acid*. Nature.
- Xue, L., Huo, J., & Zhang, Y. (2025). Modelling and analysis of an epidemic model with awareness caused by deaths due to fear. *Journal of Biological Dynamics*, 19(1). <https://doi.org/10.1080/17513758.2025.2458890>
- Zhang, M., Ma, J., Edwards, R., & Li, M. (2025). The dynamics of CD4+ T cell proliferation and regulation. *Journal of Biological Dynamics*, 19(1). <https://doi.org/10.1080/17513758.2025.2458867>
- Zhang, Y., Lai, F., Gao, S., Liu, Y., & Yan, S. (2025). Dynamical analysis of a stochastic prey–predator model with fear effect and feedback control. *Journal of Biological Dynamics*, 19(1). <https://doi.org/10.1080/17513758.2025.2479461>