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# **Construction of an Automated 3d Model of DNA to Study Structure, Base Pairing and Gene Mutation**

Ede, Onyemaechi Eze <sup>1</sup> & Ukpakara Blessing Ufuoma <sup>2</sup>

<sup>1</sup>Department of Biology Education,  
Federal College of Education (Technical) Ekiadolor, Benin City, Edo State, Nigeria

<sup>2</sup>Department of Physics Education,  
Federal College of Education (Technical) Ekiadolor, Benin City, Edo State.

## **ABSTRACT**

This project describes the design and fabrication of a motorized DNA model using iron materials for both educational demonstration and laboratory display purposes. The project aimed to produce a durable and interactive structure of the DNA model by combining biological structure and engineering principles. The double helical backbones were formed using flat iron bars, while round pipes represented the nitrogenous bases: adenine, guanine, cytosine and thymine. Four different colours (green, yellow, blue and red) were used to enhance instructional clarity and visual differentiation of the bases. A 1.5 horsepower electric motor was coupled to a self-locking worm gearbox to enhance visual comprehension of the structure, especially while rotating. The gearbox was connected to the base plate of the DNA model through the shaft, allowing a controlled and slow rotational movement for complete 360-degree viewing. The gearbox self-locking mechanism enables operational stability and safety during the demonstration session. The electric motor and gearbox assembly were enclosed in a square-shaped base constructed with metal plates for protection and structural longevity. To enhance mobility, four iron rollers were installed at the corners of the base, allowing for easy movement within the laboratory. The structure indicates that iron-based fabrication integrated with controlled mechanical rotation can generate an accurate and strong, long-lasting, and pedagogically useful DNA model suitable for scientific education demonstration and exhibition.

**Keywords:** DNA model, construction, double helix, base pairing, gene, mutation.

## **INTRODUCTION**

Deoxyribonucleic acid (DNA) is the basic molecule responsible for the storage and transmission of genetic information in organisms. In 1953, James Watson and Francis Crick discovered the double helical structure of the DNA. This brought about the revolution of modern biology, leading to the foundation for advances in genetics and molecular biology. DNA, by nature, is microscopic and cannot be viewed with unaided eye, however, its special helical structure has remained one of the most eye-catching symbols in life science.

Biology students find the three-dimensional structure of DNA interesting because its essential for understanding molecular biology. Most times, students study with textbooks, containing flat diagrams of the DNA molecule. This alone may not completely convey the real spatial arrangement of the helical backbones and the crossing bases. As a result of this, designing and constructing a physical model of DNA provides a more concrete and visual approach to enhancing understanding. When the model is well-

designed, it allows learners to comprehend the twisted nature of the molecule, the symmetrically arranged backbones, and the connecting nitrogenous base pairs in a physical format.

This project work focuses on the construction of a working DNA model using iron materials to achieve both structural strength and visual clarity. Flat iron bars were bent to form the helical strands represent the sugar-phosphate backbone, while round pipes were welded horizontally to represent the nitrogenous base pairs. To improve differentiation and instructional effectiveness, the bases were painted in four varying colors: green, yellow, blue, and red; allowing even observers to easily identify structural components and grasp their meaning. The model also incorporates a 1.5 horsepower electric motor connected to a powerful self-locking worm gearbox. The gearbox shaft is mechanically connected to the base plate of the DNA structural model, enabling steady and slow controlled rotation for full visualization. The motor and gearbox are securely arranged in an enclosed metallic base for protection and stability. Additionally, the completed system rests on four rollers firmly welded at each corner to ensure mobility within the laboratory.

### **Statement of the problem**

The structure of deoxyribonucleic acid (DNA) is essential to the learning of genetics and molecular biology. But DNA is microscopic and abstract in nature and so, students mostly find it difficult to visualize its three-dimensional double helical configuration using textbook diagrams alone. Also, conventional classroom models are small and fragile, and made from weak materials such as plastic or cardboard, which lack durability, stability, and interactive functionality.

Furthermore, many models found in schools and laboratories are static, limiting learners' ability to observe the structure from various angles or appreciate the continuous helical twist of the structural model. without dynamic visualization, engagement will be reduced which affects deeper conceptual comprehension of the spatial arrangement, base pairing, and structural symmetry of the represented molecule.

Hence, there is a need for a large-scale and mechanically interactive DNA model, providing comprehensive structural representation, long-term usability, and enhanced laboratory demonstration. The problem addressed in this project is how to design and fabricate a strong, stable, and motorized DNA model with iron materials, accurately representing the double helix and allowing or controlled rotational movement and easy mobility in the laboratory.

### **Scope of the study**

This study focuses on the design and fabrication of a large-scale, motorized DNA model with iron materials used for the purposes of educational and laboratory demonstration. The project focuses on the fabrication of a working DNA model using flat iron bars to symbolize the sugar-phosphate backbone and pipes were used to represent the nitrogenous bases. The model incorporates color differentiation: green, yellow, blue, and red to simplify visual identification of the various bases. It includes the assembly of a 1.5 horsepower electric motor with a self-locking worm gearbox to enable slow rotational movement of the model. It covers the coupling of the gearbox shaft to the base plate of the model and the enclosure of the motor and gearbox within an iron-plated base for protection and stability. Also, the installation of four rollers placed at the corners of the base, enhancing mobility of the model. However, the research is limited to the physical construction and mechanical operation of the model. It does not include biochemical analysis at the molecular level and electronic automation beyond the basic motor-driven rotation system. The study solely focuses on structural representation, durability, and educational demonstrations.

### **LITERATURE REVIEW**

The deoxyribonucleic acid (DNA) double helix, first described by James Watson and Francis Crick in 1953, marks a significant breakthrough in genetics and molecular biology (Watson and Crick, 1953). The discovery of its chemical structure brought a major change which led to understanding of genetic replication, heredity, and cellular function. Scientists, since the discovery, have recognized the limitations in communicating the spatial and structural complexity of DNA's three-dimensional configuration. This

has increased interest in the construction of physical DNA models that are more comprehensive and engaging two-dimensional textbook diagrams (Gosling and Crick, 1954; Ridley, 2004).

### **Historical Context of DNA Modeling**

In the 1950s DNA models were formed using simple materials such as metal rods, wooden dowels, and beads of various colours to signify the helical sugar–phosphate backbones and base pairs. James Watson and Francis Crick constructed the model using paper, wire, and cardboard which emphasized accurate geometry and complementary base pairing (Watson, 1968). These first models opened ways and scientists' innovative ability to construct more elaborate models used in science laboratories and classrooms to enhance understanding of biological concepts.

Physical DNA models became more widespread in the 1960s, and they were used as teaching aids. Gilbert and Osborne (1980) reported the use of a large, three-dimensional model in biology study, maintaining that constructed models helped science students understand spatial relationships in the double helix and bases. Other scientists stated that practical learning involving physical interaction with models fostered understanding of replication mechanisms and base pairing rules.

### **Educational Role of Physical Models**

A set of researches assess the relevance of physical DNA models in education. Students struggle with abstract concepts of molecular structures (Duit and Treagust, 2003). They posited that three-dimensional models act as bridges between symbolic configuration and actual biological structures. Tangible modeling helps learners to visualize the helical structure, the grooves, and the antiparallel nature of strands. This builds more comprehensive structural intuition (Gilbert, 2005).

According to studies, students tend to be more engaged when learning with models than when dealing with only textbook illustrations. For instance, instructional interventions with self-made DNA kits reported higher test scores and more learning gains. Furthermore, it was discovered that students who constructed visual DNA models performed better on visual intelligence tasks concerning nucleotide configuration than those who only viewed diagrams only (Valeeva *et al.*, 2023).

### **Materials And Methods In Model Construction**

The materials used for the construction of DNA models have advanced with design objectives. Early educational kits made use of plastic components due to their lightweight properties and ease of assembly but commercial models like those produced by BIOS Scientific used colored plastics, representing adenine, guanine, thymine, and cytosine, making nucleotide identification intuitive (BIOS Scientific, 1998).

For larger and durable demonstration models, stronger and heavier materials such as metal, wood, and acrylic have been adopted. Metal models offer more longevity and structural strength which are critical when the model is to be displayed publicly and used frequently. U. C., Davis, 1997 explained using stainless steel pipes and welded joints to construct a freestanding double helical structure which exhibits accurate configuration. Color painting was integrated to differentiate the nitrogenous bases, while maintaining visual accessibility.

More improved DNA models have been developed, integrating mechanical motion to simulate processes like unwinding which occurs during replication (Ijas, 2018). A motorized model, rotating via a mechanized base, allows observers to have a dynamic visualization of the continuous twist which enhances spatial comprehension in group scientific demonstrations.

### **Challenges and Innovation**

Although DNA models are widely used, fabricating accurate physical DNA models comes with challenges. In order to get geometric accuracy, requires measurements must be precise and attention is given to the radius, and periodicity of the helical configuration (Lehninger *et al.*, 2013). The structural integrity of large-scale models depends on material the strength of the materials used determines the structural integrity of the model and the robustness of the joint, especially when installing mechanical parts.

To overcome the incompetency of local fabrication processes, some researchers have suggested computer-aided design (CAD) and 3D printing, proving that CAD enables more precise spatial calibration and 3D printing enables production of complex components with high dimensional accuracy (Birtwell

and Saunders, 2019). They have broadened accessibility, enabling educators and students to design sophisticated models used for instructional goals.

## **METHODOLOGY**

### **Design and Planning**

A comprehensive sketch of the DNA double helix was made based on the structural model proposed by James Watson and Francis Crick. The desired height (approximately 5 feet) and spacing of the nitrogenous bases (approximately 8.2cm apart) were determined. Materials required were listed and measurements scaled accurately.

### **Materials Used**

Flat iron bars (for the helical backbone),  
Round iron pipes (for nitrogenous bases),  
Welding electrodes,  
Base plate,  
Electric motor (1.5 hp),  
Self-locking worm gearbox,  
Bolts,  
Cutting machine  
Angle bars for securing the electric motor and gearbox above the ground level  
Nuts, and  
Paints (green, yellow, blue, red)

### **Measurement and Cutting**

The bars and pipes were measured accurately measured using a tape and marked. They were then cut into required sizes with a cutting machine.

### **Formation of the Double Helix**

The measured flat iron bars were heated and bent, shaping it into a spiral form. Two identical helical frames were constructed to symbolize the sugar-phosphate backbones of the DNA model.

### **Fabrication of Nitrogenous Bases**

Round pipes were cut into equal lengths of approximately 34cm. These segments were positioned horizontally between the two helical frames at uniform intervals to represent the nitrogenous bases.

### **Welding and Assembly**

The nitrogenous base horizontal pipes were welded using electrodes and welding machine between the two helical structures. The joints were reinforced for structural strength and balance.

### **Construction of the Base Support**

A strong metal base plate was fabricated. The lower ends of the helical structure were welded securely onto the base for stability.

### **Installation of Mechanical Components**

A 1.5hp electric motor was connected through belt system to a self-locking worm gearbox, whose shaft was attached to the base plate to allow controlled rotational movement of the model. Then the mechanical components were enclosed in a metallic base, standing on four iron rollers (legs) for easy movement.

### **Finishing/Surface Treatment**

The whole fabricated structural model was cleaned to remove rust, oil, and welding residues, and a coat of anti-rust primer was sprayed on it, followed by decorative paint to differentiate structural components. Different colors were also applied to differentiate the backbone from the nitrogenous bases for clearer educational demonstration.

### **Evaluation**

The final model was evaluated based on its structural durability, stability, proportional accuracy, and visual clarity to symbolize the double helix structure of DNA. Science educators feedback was considered to evaluate its instructional effectiveness.

Through these systematic stages, the approximately 5 feet iron DNA model was constructed as a stable and durable large-scale educational tool for teaching molecular biology concepts and for scientific exhibition.

## RESULTS AND DISCUSSION

### Results

The construction of the structural model of DNA using flat iron bars and round pipes was completed. By dimension, the structure is approximately five feet in height and the helices, 0.34meters apart. The structure distinctly displayed the characteristic double helical structure of DNA described by Watson and Crick.

The flat iron bars formed two helical backbones, representing the sugar-phosphate framework of DNA structure. The round pipes, 0.34m wide, welded horizontally between the two helical frames perfectly represented the nitrogenous base pairs. Four different paint colors used (green, yellow, blue, and red) clearly differentiated the four bases: adenine, guanine, cytosine and thymine; enhancing visual comprehension.

The joints were strong and stable, and the base plate provided adequate structural support. Where a 1.5 hp electric motor and self-locking worm gearbox were installed, the model displayed smooth rotational movement upon the installation of a 1.5 hp electric motor and self-locking worm gearbox, making it more suitable for demonstration during classroom sessions. The fabricated structural model was strong, stable, and visually correct.

### DISCUSSION

The results show that in constructing a large-scale and durable DNA model, iron bars and round pipes can be effectively utilized. With the use of iron, the model tends to exhibit long-term structural strength and resistance to damage unlike wooden and plastic models. Bending the flat bars into uniform helices, however, required heating, and skilled fabrication processes to maintain accurate symmetry. Round pipes were equally spaced to maintain accuracy in proportions because misalignment in welding would disfigure the pattern of the helix. Measurement and alignment were done carefully to ensure the accurate structural representation, resembling the original molecular model first proposed by James Watson and Francis Crick.

The easy identification of the nitrogenous bases, even by mere observers, was achieved by addition of color coding. Furthermore, installing the mechanical rotation system clearly demonstrated the three-dimensional structure of the DNA model.

The major limitation observed in the structure was its weight, making it less portable. However, the structure is durable and has good strength, making it accurately suitable for laboratory science exhibition sessions.

### CONCLUSION

The construction of a working DNA model with the use of iron bars showed that concepts in biology can be perfectly represented using durable materials. The research achieved its objective of creating a 3D model of the DNA that is stable and visually accurate. The flat iron bars used to form the helical sugar-phosphate backbones and the round pipes used to represent the nitrogenous base pairs made the essential structural features of the DNA model to be clearly symbolized.

The completed model reflects both the characteristic helical shape of DNA and showcases precision in measurement and alignment. Through careful planning and accurate fabrication methods, the iron bars were successfully bent into a helical curve and uniform spacing maintained. Furthermore, the longevity and durability of the model was enhanced with the use of iron materials in comparison to conventional classroom models made from other lightweight materials. This is why it is suitable for long-term science educational display and demonstration. The project also unveils the interdisciplinary link existing between biology and engineering, showing that scientific theories can be transformed into physical structures through technical skill and creativity.

Finally, the construction of the model of DNA with use of iron bars was both feasible and educationally valuable, presenting a strong visual and structural representation of one of the most important structures in molecular biology.

### RECOMMENDATIONS

Based on the experience gained during the construction of the DNA model using iron bars, several recommendations are proposed to improve future projects of similar nature.

First, since the DNA double helix backbone needs uniform winding and equal spacing of base pairs, the use of detailed design drawings or computer-aided design (CAD) software is highly recommended to help get better symmetry and eliminate errors during fabrication processes. Second, sophisticated bending tools and mechanical rollers should be used to twist the flat iron bars into uniform helical shapes. Manual bending can easily lead to errors, which can affect the alignment of the model. Precision mechanical systems should be incorporated to provide smoother and adjustable rotation for better scientific demonstration.

Also, protective finishing like anti-rust coating, primer, and paint should be sprayed to the completed model to prevent corrosion and increase the lifespan of the model, especially for outdoor displays and in humid environments.

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