Subject Area(s)
Biology

Associated Unit
Engineering Nature: DNA Visualization and Manipulation

Lesson Title
Imaging the DNA Structure

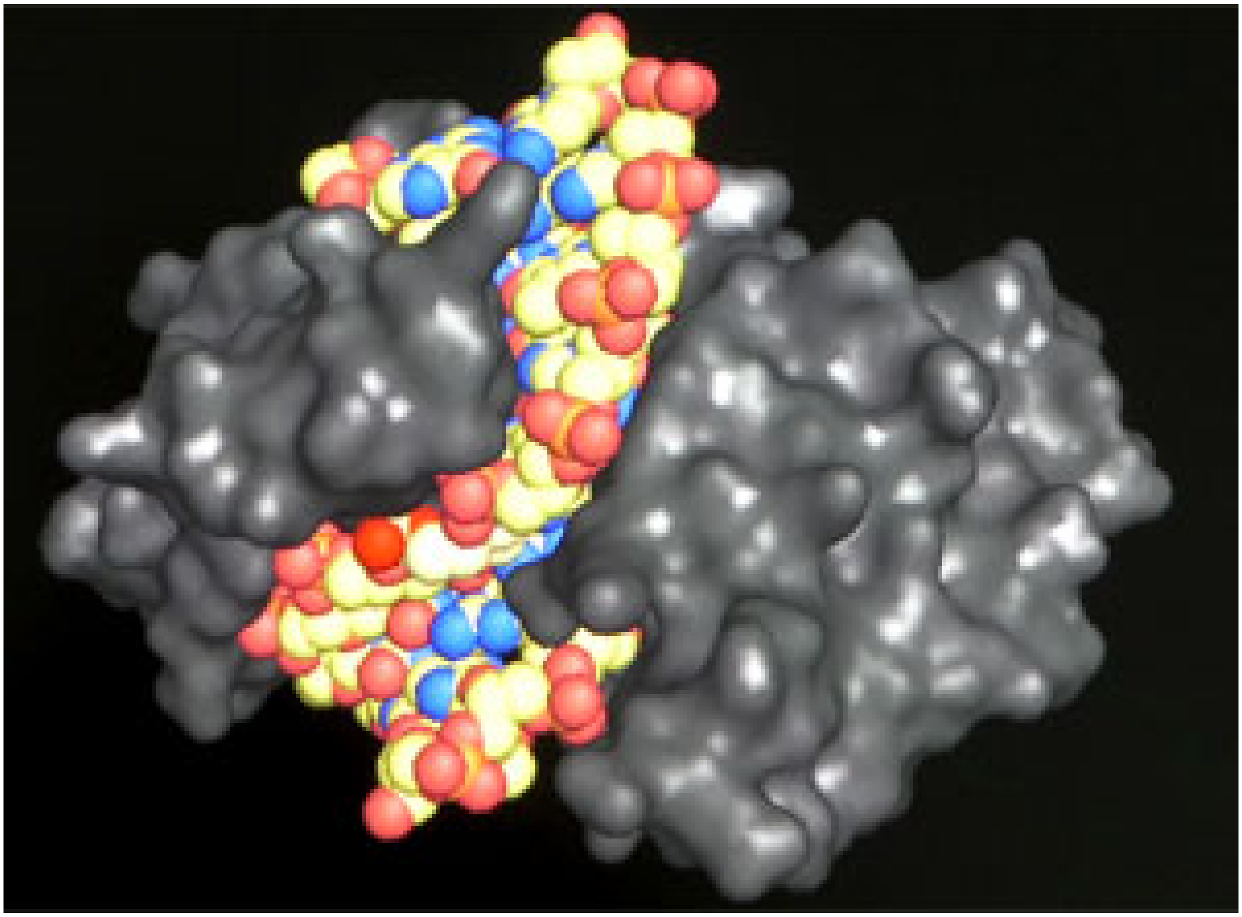

Image 1
ADA Description: Computer generated image showing biomolecules
Caption: Computer generated rendition of a restriction enzyme attached to the DNA double helix
Image file: dna-restriction-enzyme.jpg
Source/Rights: Copyright © Nature (http://www.nature.com/scitable/spotlight/restriction-enzymes-18458113)

Grade Level	10 (9-12)
Lesson #	1 of 2
Lesson Dependency	

Time Required

50 minutes

Summary

The structure of the DNA and of some proteins is very complex and the function of proteins and enzymes is dependent on

Engineering Connection

Visualization of small structures such as molecular structures of complex proteins and genetic material (DNA) is based on engineering discoveries and breakthroughs in physics at small scales. Imaging technologies such as x-ray and scanning electron microscopy—used in by scientists and engineers to image microscopic structures—are also used by biomedical engineers and biologists to study biomolecules, cells, and tissue samples. Microfluidics concepts and devices used to study colloidal particle flow are also employed by biologist to study and filter biomolecules. Gel electrophoresis is one example of engineering applications that are used by biologists to compare fragments of DNA samples.

Engineering Category = #1

Choose the category that best describes this lesson's amount/depth of engineering content:

1. Relating science and/or math concept(s) to engineering
2. Engineering analysis or partial design
3. Engineering design process

Keywords

Aorta, arteries, blood, cardiovascular, circulatory system, heart, valve, vascular, ventricle

Educational Standards

Biology: Texas Essential Knowledge and Skills (112.34. Biology, Beginning with School Year 2010--2011)

(b) (3) Scientific inquiry. Scientific inquiry is the planned and deliberate investigation of the natural world. Scientific methods of investigation are experimental, descriptive, or comparative. The method chosen should be appropriate to the question being asked.

(c) (2) Scientific processes. The student uses scientific methods and equipment during laboratory and field investigations. The student is expected to:

> (B) know that hypotheses are tentative and testable statements that must be capable of being supported or not supported by observational evidence. Hypotheses of durable explanatory power which have been tested over a wide variety of conditions are incorporated into theories;
>
> (C) know scientific theories are based on natural and physical phenomena and are capable of being tested by multiple independent researchers. Unlike hypotheses, scientific theories are well-established and highly-reliable explanations, but they may be subject to change as new areas of science and new technologies are developed;
>
> (D) distinguish between scientific hypotheses and scientific theories;
>
> (E) plan and implement descriptive, comparative, and experimental investigations, including asking questions, formulating testable hypotheses, and selecting equipment and technology;

(c) (10) Science concepts. The student knows that biological systems are composed of multiple levels. The student is expected to:

> (C) analyze the levels of organization in biological systems and relate the levels to each other and to the whole system.

Pre-Requisite Knowledge

Basic knowledge about genetics: DNA, the four nucleotide bases and the base pairing rules, DNA double helix structure.

Learning Objectives

After this lesson, students should be able to:

- Explain the function of the heart and its cycle
- Recognize the heart as a four chambered pump
- Know the difference between the atrioventricular valves and semilunar valves
- Know the most common heart problems such as valve disorders, arrhythmia, heart failures, infarction

Introduction / Motivation

Genetics and the study of biomolecules such as proteins and enzymes rely in part on theoretical/computational models and on atomic scale microscopy. In particular, the discovery of the DNA structure—the double helix—and its replication and transcription processes has led to new discoveries in molecular biology and medicine. Scientists have tried to predict the arrangement of molecules (nucleotide bases, phosphate and sugar groups) that make up the DNA using theoretical models based on the atomic and molecular interactions but no validation or comparison between the structure predicted by models and the real structure existed. In 1953, the double helix structure of the DNA based on x-ray analysis of DNA was published. It was a decade later that atomic force microscopy and other ultra-high resolution microscopy technologies were used to confirm this finding. Show students molecular images of DNA, RNA, proteins, and enzymes and ask them to guess how scientists have determined their complex shapes. How do they know that the DNA or the hemoglobin look the way they do? Is it possible to look at the crystalline structure of molecules? The answer is yes, but not by using conventional microscopy, but more complex technologies such as x-ray diffraction, transmission electron microscope (TEM), atomic force microscopy, fluorescence resonance energy transfer, magnetic resonance force microscopy, etc. What are these technologies, how do they work, what are the basic principles behind them? These are all questions that can lead to discussions about modern molecular imaging.

Lesson Background & Concepts for Teachers

The molecular structure (the shape) of chemical compounds and biological macromolecules (DNA, proteins) has been determined using X-ray but newer imaging methods such as electron microscopy and magnetic resonance are being used as well. The structures of the DNA, RNA, proteins that you have seen in many images represent schematics showing the approximated positions of the atoms form a particular molecule. These schematics as well as the crystalline structures of molecules have been constructed from data obtained from X-ray crystallography and theoretical models based on atomic and molecular interactions. It was only in the later part of the twentieth century that advancements in atomic scale microscopy have allowed the visualization of molecular structures and the validation of many theoretical models.

This lesson and its associated activity should complement the typical lesson on DNA structure or protein and enzyme structure/function. It is design to have students inquire about molecular imaging and the physics concepts behind it. The lesson should start with a discussion and presentation of the structure of biomolecules and the arrangement of atoms inside the molecules. Simple examples such as the water molecule, carbohydrates and lipids should be presented and the molecular interactions that determine the structures should be introduced with reference to previous chemistry courses. Then, more complex molecular structures should be introduced, again, discussing the effect of atomic interactions of the molecular structures and how chemical models can predict the structure.

Associated Activities
Imaging Molecules

Lesson Closure

Assessment
See the assessment for the activity associated with this lesson.

Lesson Extension Activities

Additional Multimedia Support

References

Attachments

Other

Redirect URL

Contributors
Mircea Ionescu, Myla Van Duyn

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