Subject Area(s)
Biology

Associated Unit
Engineering Nature: DNA Visualization and Manipulation

Associated Lesson
Imaging the DNA Structure

Activity Title
Inside the DNA

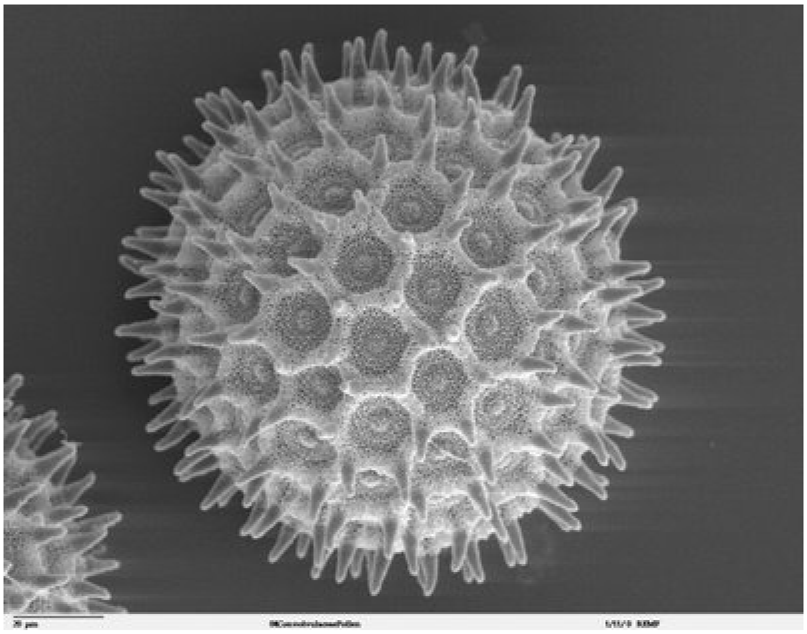
Header


Image 1
ADA Description: Black & white image of a spherical gray object with small spikes o its surface
Caption: Scanning electron image of a pollen particle
Image file: SEM.jpg
Source/Rights: Copyright © BayBLab

Grade Level
10 (9-12)

Activity Dependency

Time Required

40 minutes

Group Size

Expendable Cost per Group US$___

Summary

This activity is designed for students to discover the methods used by scientists to analyze or validate the molecular structure of DNA, proteins, and enzymes. This a computer based activity that consists of students having to research a particular molecular imaging technology such as x-ray, atomic force microscopy, transmission electron microscopy, etc, and creating a short presentation (PowerPoint) in which key points must be addressed by students.

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.

Engineering Category = #1

Choose the category that best describes this activity'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

Imaging, microscopy, x-ray, STM, TEM, AFM, FRET, magnetic resonance force microscopy

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 activity, students should be able to:

- Enumerate some of the imaging technologies used for atomic scale microscopy
- Know the basic, underlying principles of the researched microscopy method
- Describe how the microscopy method helped scientists to discover the structure of biomolecules

Materials List

Each group needs:

- Computer with Internet connection

To share with the entire class:

- N/A

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? With this introduction in mind, the students are assigned their respective microscopy technology to perform the research activity.

Vocabulary / Definitions

Word	Definition
Crystalline structure	A unique arrangement of atoms or molecules in a crystalline liquid or solid
DNA	Deoxyribonucleic acid—a self-replicating material present in nearly all living organisms as the main constituent of chromosomes
Protein	Any of a group of complex organic macromolecules that contain carbon, hydrogen, oxygen, nitrogen, and usually sulfur and are composed of one or more chains of amino acids
RNA	Ribonucleic acid, a nucleic acid present in all living cells. Its principal role is to act as a messenger carrying instructions from DNA for controlling the synthesis of proteins

Procedure

Background

Students will build a presentation based on their findings for one of the microscopy technologies listed below. Each student shall research only one technology and shall incorporate the following in their presentation:

- the date when the method/technology was first invented
- the physical phenomena involved (how it works, for example: electron scattering, nanosized probe/detector, resonant frequency—but students shouldn't go into many details, just the basic concepts
- the spatial resolution (the small object/size that can be observed)
- the use of the method in imaging DNA/proteins (look for images, if available)
- any engineering/technical challenges (design of special detectors, microscopic probes)
- cost of the device/apparatus
- where are these devices used (universities, research centers, private companies)
- images of the device
- images of DNA, proteins or other biological macromolecules obtained with the visualization method

With the Students

1. After the introduction/motivation let the students choose their microscopy technology and let them work on the research activity. The list of microscopy technologies with a suggested resource for each of them includes:
    - X-ray crystallography (http://en.wikipedia.org/wiki/X-ray_crystallography)
    - Transmission electron microscope (TEM) (http://en.wikipedia.org/wiki/Transmission_electron_microscopy_DNA_sequencing)
    - Scanning tunneling microscope (STM) (http://www.kkcryst.com/uso/3510us/Surf_Sci99.pdf)
    - Atomic force microscopy (AFM) (http://www.pnas.org/content/94/2/496.short)
    - FRET (Fluorescence resonance energy transfer) (http://jcb.rupress.org/content/160/5/629.full)
    - Magnetic resonance force microscopy (http://www.nytimes.com/2009/01/13/science/13mri.html)
    - Photo Activated Localization Microscopy (PALM) imaging (http://student.biology.arizona.edu/honors2006/group15/front15.html)

2. The assessment of each student's presentation should be based on the inclusion of each item listed in the "Background" subsection shown above.

Attachments

Safety Issues

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Troubleshooting Tips

Investigating Questions

Assessment

Post-Activity Assessment
The presentation of each student should contain all of the following:

- the date when the method/technology was first invented,
- the physical phenomena involved (how it works, for example: electron scattering, nanosized probe/detector, resonant frequency---but don't go into many details, just the basic concepts),
- the spatial resolution (the small object/size that can be observed),
- the use of the method in imaging DNA/proteins (look for images, if available),
- any engineering/technical challenges (design of special detectors, microscopic probes),
- cost of the device/apparatus,
- where are these devices used (universities, research centers, private companies),
- images of the device,
- images of DNA, proteins or other biological macromolecules obtained with the visualization method.

Activity Extensions

Activity Scaling

- For lower grades, ___?
- For upper grades, ___?

Additional Multimedia Support

References

Other

Redirect URL

Contributors

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Supporting Program
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