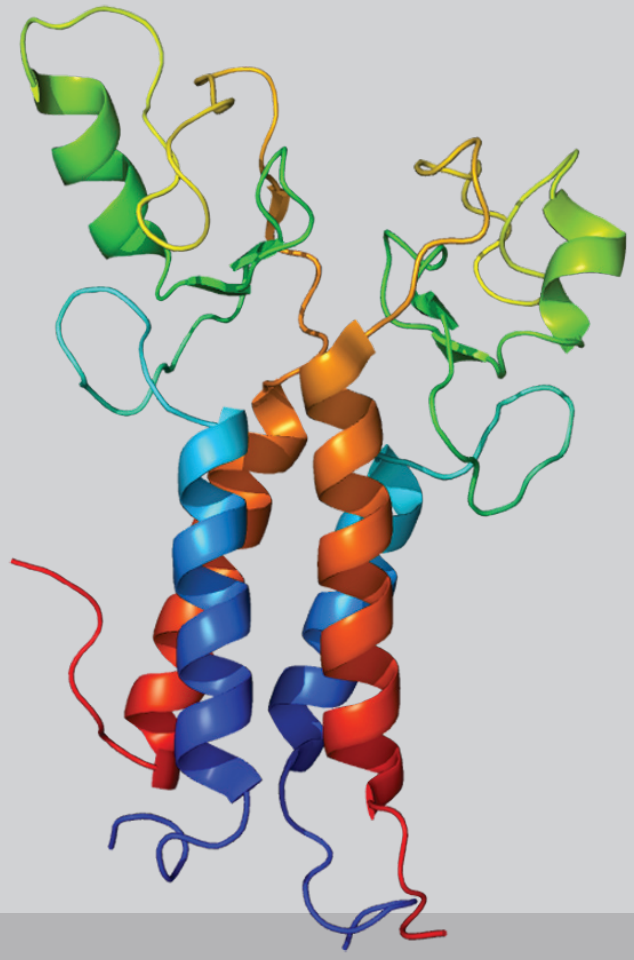

USING BIOINFORMATICS:
Genetic Testing

INTRODUCTORY

Grades 9–12 | First Edition

NWABR.ORG
Northwest Association for Biomedical Research

Credits

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Overview

Unit Overview

The curriculum unit explores how bioinformatics is applied to genetic testing. Specifically, the bioinformatics tools of BLAST and Cn3D are used to investigate the genetic and molecular consequences of a mutation to the Breast Cancer Susceptibility 1 *(BRCA1)* gene. Students are also introduced to principles-based bioethics in order to support their thoughtful consideration of the many social and ethical implications of genetic testing. Throughout the unit, students are presented with a number of career options in which the tools of bioinformatics are used.

Essential Understandings

1. Biological molecules store and process information.
2. The structure of molecules is closely related to their function. Changes in structure can often impact function.
3. Acquisition of biological information has many societal and ethical implications; students need tools to evaluate and decide how information should be used.
4. Technology influences how science is done; bioinformatics gives us new tools to understand biological information.
5. Bioinformatics is used in many areas of life sciences and related fields.

Unit Objectives

1. Students will be able to explain how bioinformatics tools are useful in analyzing biological sequence and structure information.
2. Students will be able to apply sequence analysis and protein visualization tools to explore genetic disorders.
3. Students will be able to identify and critically evaluate the ethical implications of genetic testing for individuals and their families, and society at large.
4. Students will evaluate the use of bioinformatics in the life sciences and describe how bioinformatics tools could be used in various careers.

Instructional Components

The Curriculum: The *Using Bioinformatics: Genetic Testing* curriculum consists of six sequential lessons, a seventh lesson which focuses on careers that use the tools of bioinformatics, and an assessment activity.

Throughout this curriculum, a variety of resources are provided. These materials include:

- Student "Handouts" that are designed to be printed or copied and given to each student as a "worksheet." Answers to lesson activity and/or homework questions made be completed on the handouts, on separate sheets of paper, or in lab notebooks, as desired by the teacher.

- "Class Sets" that contain lesson activity instructions for students and are designed to be printed or copied and re-used as class sets. Questions that students should answer on their handout, piece of paper, or lab notebook are indicated with an icon.

- Teacher "Resources" that include teacher demonstrations and additional information.
- Teacher Answer "Keys" that provide suggested answers and scoring information.

Time Commitment: Each lesson requires a minimum of one hour of class time. Some lessons require two class sessions, and some lessons include homework assignments. The entire unit (eight lessons) is expected to take 10–11 class periods of 50 minutes each.

Prior Knowledge Needed: This curriculum is not designed to introduce students to the "Central Dogma" of biology (that information in DNA is transcribed into mRNA and then translated into protein), but to reinforce that concept. Students should have already been exposed to DNA replication, transcription, and translation. Student understanding of these processes should be deepened through the use of this curriculum.

Career Component

Each lesson in the curriculum is accompanied by a PowerPoint slide highlighting a person in a career that uses bioinformatics, followed by a slide providing job information about that career. Student Handout—*Careers in the Spotlight* is given to students during the first lesson. Students are expected to take daily notes on this handout at the beginning of class for the duration of the unit.

Lesson Seven focuses entirely on careers that use bioinformatics. Students use interview transcripts (from professionals working in careers that use bioinformatics) and internet research to augment the information they have already constructed for Student Handout—*Careers in the Spotlight*.

Although bioinformatics is a career choice in itself, there are a wide variety of careers that use the tools of bioinformatics. This curriculum highlights a broad range of career paths, even if the use of bioinformatics within that career is not central.

Technology Requirements

For each lesson, teachers will need to be able to project a PowerPoint slide for the class to see. If this is not possible, teachers can describe the careers that begin each lesson to students based on the PowerPoint slides provided, or copy the PowerPoint slides to transparencies and project them for students using an overhead projector.

Lesson One requires the capability to show an online streaming video to the class. Alternatively, a DVD player and screen can be used if the teacher has a DVD copy of the NOVA video *Cracking the Code of Life*.

Lessons Two, *Four*, *Five*, *Seven*, and *Eight* require that students have access to both the internet and word processing software.

Lesson Five requires that the teacher project images from a computer with an internet connection. This would also be helpful for *Lessons Two*, *Four*, and *Seven*.

Lesson Five includes an animation that can be projected from the teacher's computer. This lesson also requires the Cn3D program to be downloaded and installed on all student computers. The program can be downloaded from: http://www.ncbi.nlm.nih.gov/Structure/CN3D/cn3d.shtml.

Before Beginning the Unit

Set classroom discussion norms. It is especially important to foster a safe classroom atmosphere when discussing ethical issues about genetic testing that may involve conflicting moral choices. Please review or create classroom discussion ground rules (norms) before proceeding. Instructions for doing this can be found in the Appendix.

Notify students that the class will be discussing genetics and genetic diseases, including cancer. Everybody in the classroom has been, or will be, touched in some way by this topic. Before the unit begins, give students a chance to alert the teacher to any genetic conditions or diseases that may be affecting them or their family, if the student would like to do so. Students will have different levels of comfort for discussing these issues publically.

Prepare for the Meet the Gene Machine play acted out in Lesson One. Assign the parts of Scientist and TV Talk Show Host to two willing students. Teachers may also assign the role of stage manager/director to a student who can create the minimal set and help produce the play.

Install Cn3D on all computers. Contact your school administrator or IT support staff to be sure the Cn3D program has been downloaded and installed on all student computers for Lesson Five. The program can be downloaded from: http://www.ncbi.nlm.nih.gov/Structure/CN3D/cn3d.shtml.

Additional Resources

Breast Cancer and BRCA: Background information about the structure, function, and risks associated with mutations to the *BRCA1* or *BRCA2* genes can be found in the *Appendix*.

DNA Structure: *Exploring DNA Structure* by Dr. Sandra Porter contains information on the discovery and structure of DNA along with hands-on activities that students can use to explore the structure of DNA first-hand. Students determine where molecules bind to DNA, investigate base-pairing, examine the phosphodiester backbone, and study the interaction between DNA strands. *Exploring DNA Structure* is also available on a CD together with 76 DNA structures, Cn3D, and the textbook. For more information, see www.digital-world-biology.com.

Ethics: Additional information about ethical theories and perspectives can be found in *An Ethics Primer: Lesson Ideas and Ethics Background* by Jeanne Ting Chowning and Paula Fraser, produced through the Northwest Association for Biomedical Research. NWABR's *Bioethics 101 Curriculum* provides a systematic, five-lesson introductory course to support educators in incorporating bioethics into the classroom through the use of sequential, day-to-day lesson plans. This curriculum is designed to help science teachers in guiding their students to analyze issues using scientific facts, ethical principles, and reasoned judgment. The complete *Ethics Primer* and *Bioethics 101* are available free for download from http://www.NWABR.org.

Molecular Structures: Have you ever wanted to find molecular structures that you can use as class examples? *A Beginner's Guide to Molecular Structure*, by Dr. Sandra Porter, navigates through the NCBI databases to help teachers determine if structures come from normal or mutant proteins, and to identify the parts of the protein that are found in the structure. Activities include superimposing influenza structures to see why one strain could become resistant to Tamiflu, working with green fluorescent protein, and more. For more information, see http://www.digital-world-biology.com.

Lesson Overview

Lesson One: Bioinformatics and Genetic Testing

A short topical play introduces students to the fields of bioinformatics, genetic testing, direct-to-consumer genetic testing, and ethical considerations. Students discuss some of the broad implications and ethical questions raised from gaining information through genetic testing. Students then consider a number of genetic tests and their potential usefulness and value and, as a class, explore the website of 23andMe, a company that offers direct-to-consumer genetic tests. The lesson wraps up as it began—by engaging students in a story. Through a short video, students are introduced to a family impacted by breast cancer. In Lesson One, students also learn how ***bioengineers*** might use bioinformatics tools in their career.

Lesson Two: Navigating the NCBI

Students navigate parts of the National Center for Biotechnology Information (NCBI) website and work independently to explore databases, focusing on the *BRCA1* gene and the bioinformatics tool Map Viewer. Through an analogy that compares two collections of databases (iTunes® and the NCBI), students connect with their own prior knowledge to better understand database structure and function. In *Lesson Two*, students learn how ***veterinarians*** might use bioinformatics tools in their career.

Lesson Three: Exploring Genetic Testing: A Case Study

In this lesson, students engage in a case study about a family with a history of breast cancer. Students consider ethical issues surrounding genetic testing as they decide whether or not family members should get tested for *BRCA1* or *BRCA2* mutations. Students then evaluate the case through the principles-based bioethics concepts of: Respect for Persons, Maximize Benefits/Minimize Harms, and Justice. Students apply the principles to help them reason through their decision as they participate in a Structured Academic Controversy. In *Lesson Three*, students learn how ***genetic counselors*** might use bioinformatics tools in their career.

Lesson Four: Understanding Genetic Tests to Detect *BRCA1* Mutations

Students begin this lesson by working through a pedigree chart and Punnett squares for the Lawler family, attempting to track the *BRCA1* mutation across generations. Based on the decisions as to who should be tested for the *BRCA1* mutation, students then use the bioinformatics tool known as BLAST (Basic Local Alignment Search Tool) to compare individual DNA and protein sequences to reference sequences that are known to be free of *BRCA1* mutations associated with cancer. At the end of the lesson, students compile class information from the Lawler family in order to revise their pedigree charts and Punnett squares. In *Lesson Four*, students learn how ***laboratory technicians*** might use bioinformatics tools in their career.

Lesson Five: Learning to Use Cn3D: A Bioinformatics Tool

Up to this point, students have seen the BRCA1 protein represented in a linear, sequential form. In this lesson, students are introduced to the high importance of a protein's three-dimensional structure. Students first engage in a short activity in which they use a pipe cleaner to perform a simple function, as an analogy for the relationship between a protein's structure and function. Students then learn to navigate between linear protein sequences and three-dimensional structures by using the bioinformatics tool Cn3D. Students begin by viewing and manipulating DNA—a familiar molecule to students—using Cn3D. When students are familiar with the program, students visualize parts of the BRCA1 protein to show how a specific mutation in the *BRCA1* gene ultimately changes or destroys the protein's function. In *Lesson Five*, students learn how ***3D animators*** might use bioinformatics tools in their career.

Lesson Six: Evaluating Genetic Tests: A Socratic Seminar Discussion

In this lesson, students apply the ethical skills and scientific knowledge they have acquired over the previous lessons to determine (1) whether *BRCA1* testing meets the standards of a useful genetic test, or (2) whether direct-to-consumer genetic testing should include genetic counseling of clients. Students or teachers may choose from one of two readings, after which students participate in a Socratic Seminar in order to deepen their understanding about genetic testing. Through the seminar discussion of the first reading, students become familiar with a framework for considering genetic tests in terms of their clinical validity and the availability of effective treatment. Through the seminar discussion of the second reading, students become familiar with issues and preliminary data regarding the effects of direct-to-consumer genome-wide screening. After the seminar, students are supported in coming to an individual position about genetic testing through the integration of scientific facts, stakeholder viewpoints, and ethical considerations. In *Lesson Six*, students learn how ***bioethicists*** might use bioinformatics tools in their career.

Lesson Seven: An Introduction to Bioinformatics Careers

In this lesson, students explore more deeply the information they have learned throughout the unit about people in various careers that use bioinformatics. Students choose one career they would like to learn more about. They further explore that career by reading a series of in-depth questions asked of the person highlighted in that career, as well as provided internet resources. Students then respond to a job posting for a summer internship in their chosen field, developing a resume for that position. Optional activities include peer-editing of resumes and socializing in a professional environment.

Lesson Eight: Genetic Testing Unit Assessment: *ALAD* and *SOD1*

As an assessment of the unit, students revisit some of the bioinformatics tools they have used in prior lessons in order to locate a mutation in a protein associated with a genetic condition. Students also evaluate current genetic tests for the condition using the criteria of clinical validity and treatment options. Two conditions and their tests are presented: porphyria and amyotrophic lateral sclerosis (ALS).

National Science Education Standards

	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Lesson 7	Lesson 8
Science as Inquiry								
Abilities necessary to do scientific inquiry		•		•	•		•	•
Understandings about scientific inquiry	•			•	•	•	•	•
Science and Technology								
Abilities of technological design	•	•		•	•	•	•	•
Understandings about science and technology	•	•	•	•	•	•	•	•
Science in Personal and Social Perspectives								
Personal health and community health	•	•	•	•	•	•	•	•
Science and technology in local, national, and global challenges	•	•	•	•	•	•	•	•
History and Nature of Science								
Science as a human endeavor	•	•	•	•	•	•	•	•
Nature of scientific knowledge	•	•	•			•	•	•

Source: National Research Council. (1995). *National Science Education Standards.* Washington D.C.: National Academies Press.

Next Generation Science Education Standards

	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Lesson 7	Lesson 8
Scientific Practices								
1. Asking Questions	•	•	•	•	•	•		•
2. Developing and Using Models								
3. Planning and Carrying Out Investigations		•		•	•			•
4. Analyzing and Interpreting Data		•		•	•			•
5. Using Mathematics, Information and Computer Technology, and Computational Thinking		•		•	•			•
6. Constructing Explanations	•	•	•	•	•	•		•
7. Engaging in Argument from Evidence			•			•		•
8. Obtaining, Evaluating, and Communicating Information	•	•	•	•	•	•	•	•
Crosscutting Concepts								
Patterns								
Cause and Effect: Mechanisms and Explanation		•		•	•			•
Scale, Proportion, and Quantity								
Systems and System Models								
Energy and Matter: Flows, Cycles, and Conservation								
Structure and Function				•	•			•
Stability and Change								
Core Ideas: Life Sciences								
LS 1: From Molecules to Organisms: Structures and Processes								
LS 2: Ecosystems: Interactions, Energy, and Dynamics								
LS 3: Heredity: Inheritance and Variation of Traits		•	•	•	•			•
LS 4: Biological Evolution: Unity and Diversity		•						

Source: Committee on Conceptual Framework for the New K-12 Science Education Standards, National Research Council. (2011). A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Washington D.C.: National Academies Press.