UNIT 3
Biotechnology: The Polymerase Chain Reaction (PCR)

Unit Overview

I. Introduction

To many people, the word biotechnology brings images of genetically altered organisms and cloning. These images conjure up ideas of futuristic technologies that are unnatural, out of control, and developing too quickly for us to manage. Although it is true that biotechnology has grown immensely during the past few decades, it has been around for a very long time. Biotechnology did not have a name until the early 1900s, but it dates back to the beginning of civilization when the fundamentals of biotechnology were born—the manipulation of natural, living systems to meet specific human needs. Ancient peoples like the Summerians, Babylonians, and early Egyptians figured out a ways to manipulate yeast, bacteria, and molds to make bread, beer, wine, vinegar, and cheese. Later on, humans figured out ways to selectively breed plants and animals to increase agricultural production and increase their chances for survival. As with all technologies, human need and want provides the impetus for driving biotechnological invention and development.

Biotechnological processes discovered millennia ago are still currently practiced, but biotechnology today is very different than it was back then. For one thing, we have a fuller understanding of why and how it works and so we have refined these processes to better meet our needs. Most importantly, modern biotechnology has taken the molecular route, meaning that most biotechnologies we hear about today deal with the manipulation of organisms at the molecular level. These developments became possible with the advent of DNA science, which in turn led to DNA technology, an integral element in the advancement of DNA science. Most people use the terms science and technology interchangeably, yet there is a key difference between science and technology. Science is grounded in the quest for understanding of the natural world. Technology involves the use and manipulation of raw materials, whether natural or man-made, to make products that have the potential to improve human life by meeting human needs or wants.

Biotechnology, like any technology, involves the manipulation and use of raw materials, but in this case, the raw materials are living organisms and systems.

Today, biotechnology is all around us—in newspapers, news broadcasts, popular magazines, and other popular media. Headlines such as "DNA Solves Murder Case," "Making Better Cows," "University Speaker to Talk about Cloning," "Pest-Free Rice" are common and difficult to escape. While some news is comforting, like the use of DNA to solve murder cases and serve justice, other news such as cloning, stem cell research, and genetically modified organisms often lead to uncertainty, confusion, and even fear. There is not one of us today that is not touched by biotechnology. We are all living through a biotechnology revolution that will most definitely influence if not shape our future society. For this reason, it is important that we all attain some level of understanding about what some of the leading biotechnologies are—what they are used for, how they work, and how they affect our world. How do they apply to areas such as forensic science, diagnostic medicine, scientific research, and agriculture? To understand issues in biotechnology that may be of public concern, we must take a seat at the genetic engineer's workbench and learn about the technologies that are commonly used.

The polymerase chain reaction (PCR), a technique that allows scientists and technologists to isolate and copy DNA millions of times, has become commonplace in most DNA labs. The PCR has made it possible to take minute samples of DNA and produce sufficient amounts of DNA for proper analysis. By manipulating naturally occurring mechanisms of DNA replication, the PCR pinpoints a specific location on a DNA molecule, and then duplicates that location over and over, leaving just the DNA of interest for analysis. The PCR may be used as the starting point for analyzing DNA from a crime scene, scanning agricultural products for genetic modifications, running paternity tests, and diagnosing diseases. Becoming knowledgeable about these and other technologies will give us the power to make better decisions about how to manipulate our world in a way that does not damage our environment, our society, or our very own human species.

II. Unit Learning Goals

- To give students a historical overview of biotechnology by focusing on a key biotechnology, the polymerase chain reaction (PCR), to understand how and why this technology is used.
- To give students the opportunity to gain a basic understanding of key biotechnology principles associated with PCR such as the basic DNA structure, the mechanics of the PCR process, and the automation of the PCR process.
- To give students the opportunity to delve into the applications of PCR and related biotechnology.
- To allow students to explore the ethical and societal implications of current biotechnology issues such as genetically modified organisms and DNA profiling.

III. Unit Connections to ITEA's Standards for Technological Literacy

This unit is focused on Agricultural and Related Biotechnologies of the Designed World, Standard 14, and Information and Communication Technologies of the Designed World-Standard 17. The following matrix identifies the Standards for Technological Literacy that are addressed by the projects within the unit. Project extensions and advanced level projects may cover additional standards.

Unit 3	Biotechnology: The Polymerase Chain Reaction (PCR)																		
Target Standards for Technological Literacy																			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Introductory Level Projects																			
Project 1-Biotechnology and History	X	X	X			X	X				X	X			X		X		
Project 2-The PCR Process								X		X	X		X		X		X		
Prroject 3-The PCR Machine								X		X	X	X	X		X		X		
Project 4-Biotechnology and Society: GMOs				X	X	X	X				X	X			X		X		
Intermediate Level Projects																			
Project 5-Forensic Science	X	X	X			X	X				X	X			X		X		
Project 6-PCR and DNA Fingerprinting								X	X	X	X	X			X		X		
Project 7-Forensic Animation								X	X	X	X	X	X		X		X		
Project 8-DNA Profiling				X	X	X	X				X	X			X		X		

IV. Navigating the Unit

The biotechnology unit is ideally navigated in a sequential manner starting at the introductory level and progressing through the intermediate level and then to the advanced level. Project 1, Biotechnology and History, provides an important historical overview for PCR, but is not absolutely necessary for completing Project 2, The PCR Process. However, Project 2 should be completed prior to attempting Project 3, The PCR Machine. Project 4, Biotechnology and Society: Genetically Modified Organisms (GMOs) focuses on ethical issues and can be done at any point, including after completing Intermediate level projects. The Intermediate level projects are structured similarly, with Project 5, Forensic Science, providing a historical overview, Project 6, PCR and DNA Fingerprinting, and Project 7, Forensic Animation that focuses on the technology, and Project 8, DNA Profiling, that centers on ethics. If limited on time, any of the projects in the Intermediate level can be done in any order.

V. Projects

Introductory Projects

Project 1: Biotechnology and History

Students will research and present historical aspects of biotechnology, focusing on the polymerase chain reaction (PCR) technology to understand why this technology is needed, how it came to be, and its current applications.

Project 2: The PCR Process

Students will simulate the PCR process by building a DNA model and taking it through the PCR process. They will also visually represent data collected during the simulation.

Project 3: The PCR Machine

In this project, students will learn about the PCR machine and its role in DNA replication. They will be introduced to the fundamental technology underlying the device and have the opportunity to explore these concepts through diagramming the steps of the PCR cycle. The project concludes with students exploring how low-tech versions of the machine might be built for use in developing nations.

Project 4: Biotechnology and Society: Genetically Modified Organisms

Students will gather information and discuss the impacts that advancements in biotechnology have on society by focusing on genetically modified organisms (GMOs). In this project, students will hold a forum on the impact of GMOs and develop a brochure about GMOs that can be distributed in their local community.

Intermediate Projects

Project 5: Forensic Science

Students will research and present historically significant accounts in forensic science to develop an understanding of the key developments in technology that have spurred major advancements in forensic science.

Project 6: PCR and DNA Fingerprinting

Students will use visualization tools to simulate how DNA from a crime scene is collected, processed, and amplified using PCR and then analyzed by DNA fingerprinting techniques.

Project 7: Forensic Animation

Students will explore forensic animation by graphically simulating a crime scene based on a documented crime that relied on DNA evidence and DNA technology for its solution.

Project 8: DNA Profiling

Students will research and debate the advantages and disadvantages of DNA profiling and its impact on society by focusing on issues surrounding DNA storage and cataloguing.

Advanced Projects

Students will complete an independent project through the use of visualization tools by researching a new topic dealing with PCR, DNA fingerprinting and forensic science, or by expanding on topics covered in this unit. The objective of the advanced level is for students to further their skills in integrating research, problem solving through the design brief approach, and presentation. It is up to the teacher to work with students to negotiate the topic, time allocated to the project, and design constraints.

VI. Unit Resources

The Resource index document contains a listing of all resources associated with the Unit. Included are relevant web site links, books and other publications. Listed in the document are additional files found in the Resources folder under each Unit folder on the CD-ROM. Also included are the Glossary, Evaluation rubric, Lecture PowerPoint slides, and Unit test questions.