Curriculum Units by Fellows of the National Initiative
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Introduction

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One of the most well-known stories in science involves the discovery of the structure of DNA, which was accomplished by James Watson and Francis Crick in 1953, when both were young men working at Cavendish Laboratory in Cambridge, England. Watson's autobiographical book, *The Double Helix*, describes that period of accomplishment, but it retains its popularity because it deals directly with a more general theme. It might be the best description for modern readers of the magical quality of science and its appeal for young people seeking adventure and fame. In this way, the story of DNA, beginning with its unveiling, has been linked to romance, celebrity, and power.

DNA is worthy of this glamour. Nucleic acids are the key information storage molecules of life. Genetic information is encoded within the nucleic acids of almost every cell in our body, where it is capable of being inherited from one cell to the next, generation after generation. The study of nucleic acids is multifaceted: it involves examination of the structure and function of nucleic acid polymers, the capacity of these molecules to hold information, the changes in information content that happen upon modifications of nucleic acids, the diverse roles of nucleic acids in the life of a cell, and the characteristics that make them useful tools in biotechnology and bioengineering. DNA is also intimately involved in human health. Many diseases result from failures at the DNA level. These failures can arise from defects in genes themselves (causing genetic diseases) or in the regulatory regions of genes (causing cancer). Some diseases are the result of a defect in a single gene. Although many of these diseases are rare, some—such as cystic fibrosis and muscular dystrophy—are relatively common. Many scientists and engineers are now involved in the search for safe and effective methods for gene therapy in humans, in the hope that the defective genes can be replaced with new functional genes, which will cure the disease.

From the origins of recombinant DNA technology in the 1970s, our society has quickly gained the capability to manipulate and use DNA as a tool for understanding and treating disease. DNA technology has also changed the way that we manufacture drugs. Human genes can now be inserted safely and efficiently into bacteria, yeast, viruses, or animal cells. This capability has already led to the production of recombinant proteins as therapeutic drugs; diabetics around the world now use recombinant human insulin that is safer and cheaper than previous insulin drugs, which were harvested from animal tissues. DNA technology is also changing forensic science, agriculture, and other aspects of contemporary life. Some bioengineers are even learning how to use DNA as a tool, deploying DNA molecules as molecular Tinker Toys for building tiny but well-defined objects.

This seminar examined nucleic acids, beginning with an introduction to the science of genetics and ending with descriptions of some of the ways that DNA is now used in human health. Along the path from genetics to bioengineering, the seminar focused on the structure of nucleic acids and the basic concepts underlying molecular biology. The seminar also made excursions into the field of biotechnology, which harnesses what we know about DNA to manufacture new medicines, to improve foods, and to treat diseases where medicines fail. The curriculum units that were produced in this seminar should be of interest to teachers in science, mathematics, and health. In addition, because there is so much material now written about the science of DNA and its impact on society, this seminar may be of interest to teachers interested in how students can read for information.

Specifically, the seminar covered the following topics:

1. Introduction to molecular biology
2. Introduction to genetic engineering
3. Tools of genetic engineering: host cells and vectors
4. Medical applications of gene manipulation
5. Forensic applications of genetics
6. Genes and genomes (with a visit to Yale's West Campus, Genome Analysis Center)
7. Polymerase chain reaction
8. Transgenic plants and animals

The discussions in the seminar were enhanced by our reading from: *Introduction to Genetic Engineering, Third Edition*, D.S.T. Nicholl, Cambridge University Press (2008); and *Biomedical Engineering*, W. Mark Saltzman, Cambridge University Press (2009).

The Fellows prepared curriculum units that covered a breadth of information on genes and genetic engineering. The material presented in the units assembled in this volume span an impressive range and are designed for use in classrooms from elementary through high school.

Many of the units focused on material that is appropriate for high school students. Amanda Issa wrote a unit called "Genetically Engineering Cures for Single Gene Diseases," which provides a sound review of the principles of modern gene therapy, focused on four diseases that result from single gene defects: Huntington's disease, sickle cell anemia, hemophilia, and cystic fibrosis. Her unit provides a description of the genetic basis of each of these diseases, as well as descriptions of how changes in the gene affect the physiology of individuals. Further, she challenges students to think about new approaches for correcting or reversing the genetic defects. Vanessa Vitug produced a unit titled "DNA in Forensic Science," which she uses to present information on the molecular biology in the context of forensic science. The unit covers a range of important and timely topics, including DNA fingerprinting and role of polymerase chain reaction (or PCR) in crime scene analysis. Timothy Spence prepared a unit titled "HIV: From Horror to Hope." His unit, designed for high school mathematics and biology teachers, describes the early history of the AIDS epidemic and the unraveling of the mystery of its cause, through discovery of the structure and genetic characteristics of the human immunodeficiency virus (HIV). Importantly, he describes how the special properties of that virus make it one of the most promising vehicles for treating genetic diseases. Timothy also provides examples of how mathematics teachers can use genetic principles as the basis of real-world applications of statistics and mathematics.

Three of the units in this volume focus on the use of DNA in agriculture and, in particular, on important issues surrounding genetically-modified foods. Two of the units are prepared for high school classrooms. Maria Orton's unit, called "Effects of Genetically Modified Organisms on Agriculture," approaches the topic from the point of view of chemistry, examining the differences that result in agricultural products as a result of genetic modifications. By presenting a topic that is important to every student and parent—how safe is the food that you eat?—the unit provides a practical example of the relevance of chemistry in all of our lives. Stuart Surrey wrote a unit called "Controversial Issues Regarding the Consumption of Genetically Modified Crops" which focuses on both the means of production of genetically modified foods and the history of their development. Laura Kessinger explores many of the same themes in her unit, "The Evolution of Genetic Engineering." Laura's unit was designed for elementary school students, but should also to appropriate for many middle school classrooms, as well. Importantly, in each of these units, Stuart and Maria and Laura provide scientific material that allows teachers and students to explore the pros and cons of genetic engineering in agriculture.

Laura Carroll-Koch prepared a unit called "Harnessing the Power of DNA," which was designed for elementary school teachers and students. Her unit provides a description of the basic science of DNA and molecular biology, including a presentation of ways to use this information to treat diseases that have proven very difficult to treat. Laura also brings to the foreground a theme that is present in all of the units in this volume: teachers can generate excitement in their classrooms by exposing their students to new concepts in genetics and genetic engineering, with the hope that many young people will be inspired to careers in science, to help realize the potential for science and engineering to improve the lives of the world population.

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