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ABSTRACT

Presented at a 1996 conference on the implications of the Human Genome Project for community and technical colleges, the 30 papers included in this monograph describe methods for incorporating genetics studies into the two-year college curriculum. Among the papers provided are: (1) "Facing the Unknown: The Ethical Challenges of Biotechnology" (J. Buchanan); (2) "Disclosure of Genetic Information to Family Members: Ethical and Legal Implications" (K. Gottlieb); (3) "The Genetics Revolution: Toward a Sense of Ownership" (R. Badra); (4) "'The Twilight of the Golds': A Paradigm for Ethical Considerations in the Genetics Revolution Discussion" (L. Coleman); (5) "The Third Genie: Genetic Considerations at the Community College Level" (A. Hunt); (6) "Bioethics in the Classroom" (K. Armstrong); (7) "David's Dance: Historical Responses to Genetic Knowledge" (W. Yarbrough and M. Pittman); (8) "Educating the Educators: The Genetics Revolution in the Community College Setting" (J. Dario-Becker); (9) "Field of Dreams--'Build It and They Will Come': Building a Program in Genetics at the Community College" (C. Urbano); (10) "Chromosomes: The Crucial Road Maps for Molecular Genetic Studies" (D. Dailey); (11) "Transgenic Crops: New DNA in Your Food" (P. Mangum); and (12) "Incorporation of the Human Genome Project into a Human Genetics Course for Allied Health Fields" (K. Finer). The conference program is appended. (BCY)

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The Genetics Revolution

Programs and Issues for the Community College

a monograph highlighting the winners of the Exxon
Education Foundation Innovation Awards

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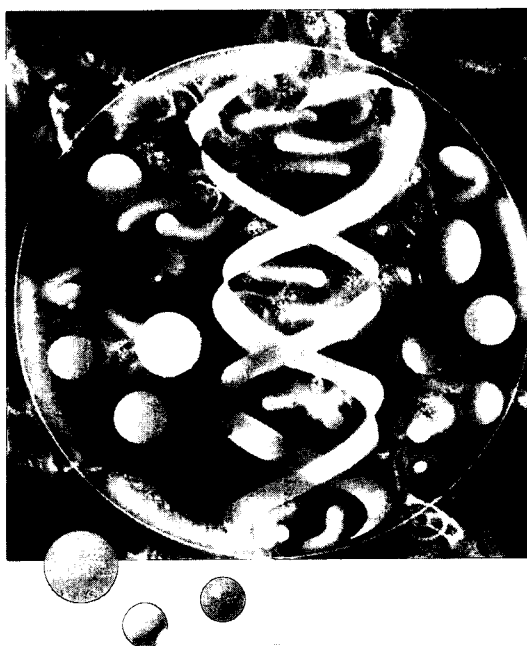
Introduction by J. Craig Venter

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The Genetics Revolution

The Genetics Revolution

Programs and Issues for the Community College



A monograph highlighting the winners of the Exxon Education Foundation Innovation Awards. These papers examine the latest research in genetics and the related ethical, philosophical, and public policy issues from the perspective of the community college. They were presented at a conference hosted by North Lake College and the Dallas County Community College District March 21–23, 1996, in Dallas, Texas.

Edited by Marilyn Elaine Mays

Introduction by J. Craig Venter

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Contents

Foreword	ix
Community Colleges and the Genetics Revolution	xi
Preface	xiii
Acknowledgments	xvii

Introduction: Status of the Human Genome Project	1
<i>J. Craig Venter</i>	

Part I: Ethical, Legal, and Social Issues

1. Facing the Unknown: The Ethical Challenges of Biotechnology	5
<i>James Buchanan</i>	
2. Disclosure of Genetic Information to Family Members: Ethical and Legal Implications	11
<i>Karen Gottlieb</i>	
3. The Genetics Revolution: Toward a Sense of Ownership	18
<i>Robert Badra</i>	
4. <i>The Twilight of the Golds</i> : A Paradigm for Ethical Considerations in the Genetics Revolution Discussion	23
<i>Landon Coleman</i>	
5. The Third Genie: Genetic Considerations at the Community College Level	26
<i>Allen N. Hunt</i>	
6. Bioethics in the Classroom	30
<i>Kerri Armstrong</i>	
7. David's Dance: Historical Responses to Genetic Knowledge	33
<i>Warren Yarbrough, Mary Pittman</i>	

Part II: Biology, Nursing, and Allied Health Courses

8. Educating the Educators: The Genetics Revolution in the Community College Setting	41
<i>Juville G. Dario-Becker</i>	
9. Field of Dreams—"Build It and They Will Come": Building a Program in Genetics at the Community College	48
<i>Charissa Urbano</i>	
10. Chromosomes: Crucial Road Maps for Molecular Genetic Studies (BB)	51
<i>D. Charles Dailey</i>	

11. Transgenic Crops: New DNA in your Food 57
Paul Mangum
12. Incorporation of the Human Genome Project into a Human Genetics Course
for Allied Health Fields 65
Kim R. Finer
13. Integrating Genetic Knowledge into Community College Nursing Education 69
Felissa R. Lashley
14. Introducing Concepts and Skills in DNA Technology (BB) 73
Phil Shelp, Karen Bentz, Fredella Wortham
15. Human Genetics 77
Joyce M. Greene
16. Multimedia Approach to DNA Teaching 82
Adriana Cobo-Frenkel
17. Discovering Genetics through Field Trips 85
Barbara J. McCormick
18. A Combination of Laboratories in Biotechnology Demonstrating
the General Approach of the Human Genome Project (BB) 88
Joan McCoy-Messer
19. A Laboratory Approach to Molecular Genetics as an Adjunct to a General Biology
Sequence and Clinical Chemistry Course (BB) 91
Thomas P. Arnold, Nancy York
20. A DNA Fingerprinting Exercise for Any Type of Class (BB) 94
Sandra G. Porter

Part III: Biotechnology Programs

21. An Interdisciplinary Approach to Genetics in a Biotechnology Program 103
Barry Werner, Mariluci Bladon, Julien Farland, Mary Lee Underhill
22. Instilling Job Literacy for Current and Upcoming Biotechnology Occupations 108
Brian R. Shmaefsky
23. Growing a Community College Biotechnology Program through Collaborative
Partnerships 112
Elaine A. Johnson
24. An Applied Biotechnology Capstone Course: Melding the Resources of the
Community College and Industry 117
Dave Singer

25. Biotechnology at William Paterson College: Educating Students for the Genetics Revolution 122
Miryam Z. Wahrman, Jane R. Voos, Robert H. Chesney, Jean M. Werth, E. Eileen Gardner

Part IV: Multidisciplinary Approaches

26. A Multidisciplinary Approach to the Human Genome Project 129
Bob Bermant, John Knight
27. Genes in the Making: Human Genetics for General Education in Community Colleges 134
Ram Nayar
28. Educational Catalysts and Their Implications 137
Richard Effland, Shereen Lerner, Jack Peterson
29. A Learning Community Biotechnology Curriculum 142
James Monroe, David Muga
30. An Interdisciplinary Honors Course Explores the Scientific, Ethical, and Historical Aspects of Genetics 148
Johanna Kruckeberg

Appendixes

1. Conference Program for The Genetics Revolution: A Catalyst for Education and Public Policy 153
2. Directory of Exxon Education Foundation Innovation Award Winners 159

Index 163

Most of the papers in the monograph are geared toward a general audience. Some technical language is used, but a technical background is not essential to understanding the papers. Five papers are coded BB to indicate that the papers assume a biology background.

Foreword

On March 21, 1996, a conference on the Human Genome Project and its implications for community and technical colleges was held at the Hyatt Regency Hotel in Dallas. This conference, *The Genetics Revolution: A Catalyst for Education and Public Policy*, and the resulting monograph are the product of the creative imagination of Jim Horton, then president of North Lake College. They represent one of the most exciting and important projects launched by the Dallas County Community College District, the Exxon Education Foundation, and several other cooperating institutions.

Many people asked why the Dallas Community College District and other community college organizations dedicated to teaching and learning were developing, sponsoring, and hosting a conference on complicated DNA research leading to the sequencing of the human genome. Granted, the United States' long-term research commitment to sequence all 100,000 or so human DNA strands was one of the most significant collaborative research commitments ever undertaken by American research institutions, but why were community colleges so interested at the research stage? The answer is, of course, that the Human Genome Project has such significant implications for so many aspects of human existence that we can ignore it only at our own peril.

The sequencing of the entire human genome raises biological, medical, sociological, public policy, educational, and a whole host of other issues related to the prevention and cure of disease, the positive and negative aspects of cloning, the development of replacement body parts, and the moral/theological/ethical questions of human existence. The implications of human genome research cut across all the artificial barriers between technical and general education at our colleges. Clearly, new and yet unknown occupations will develop that will require technical education at community colleges. But, even more important, human genome research will affect what and how we teach many core courses including biology, chemistry, ethics/philosophy, political science, and sociology. We will be disseminators of its impact to our larger constituency through community service and community learning.

Recent announcements about the successful cloning of sheep and primates have resulted in a public hue and cry regarding human cloning—one of the potential outcomes of the human genome research. Even the most astute of us cannot predict where this knowledge will lead. None of us, especially in learning organizations such as community colleges, can afford to ignore what is happening. This is just the beginning.

J. William Wenrich
Chancellor
Dallas County Community College District

Community Colleges and the Genetics Revolution

Community colleges are a fertile field for the growth and development of tomorrow's scientists. For living proof, one must look no farther than J. Craig Venter, founder, president, and CEO of The Institute for Genomic Research (TIGR) in Gaithersburg, Maryland. The community college was Venter's introduction to higher education. Upon returning from his tour of duty in Vietnam, Venter enrolled at the College of San Mateo, a community college in California. Six years later he had completed his Ph.D. in physiology and pharmacology from the University of California, San Diego. In 1992, after an eight-year stint as a research scientist with the National Institutes of Health, he created TIGR.

Venter is at the forefront of what may well be the most profound scientific endeavor to date, genomic research. Among his many contributions is the development of a strategy that has accelerated the pace of gene discovery 1,000-fold over previously used methods. Thus Venter was a natural choice to give the keynote address for the March 1996 conference *The Genetics Revolution: A Catalyst for Education and Public Policy*, which brought community college educators from across the nation together to explore their roles in genomic research. For Venter and many other scientists, community colleges have provided a catalyst for the curiosity and subsequent research that has fueled scientific endeavors such as genomic research; and community colleges have an increasingly important role to play in the genetics revolution.

Given its innumerable potential outcomes, genomic research must be interpreted for those who are neither scientists nor educators. The general population must understand the scientific, ethical, legal, and social issues of this profound science. What better venue than the community college, which since its advent has played a critical role in the process of continuous education? More than 1,100 community colleges throughout the United States routinely provide continuing education to significant portions of their communities. Community colleges not only have the infrastructure to disseminate scientific information but also can provide a structured and impartial venue for broad-based discussions about the application of the powerful technology that is a by-product of the Human Genome Project. Community college faculty rarely have the opportunity to satisfy their need for learning cutting-edge information from the world's top scientists while sharing their teaching methodologies and research.

The Genetics Revolution conference provided an opportunity to showcase community college faculty and students in an arena that is normally the sole purview of universities. In the course of three days, participants learned from scientists and fellow educators new ways of incorporating the study of human genetics into their various curricula. At the same time, North Lake College, the Dallas County Community College District, and the Exxon Education Foundation created a model for effective dissemination of complex scientific and ethical concerns in an inclusive environment that mirrors the world in which we live.

James F. Horton Jr.
Chancellor, San Jacinto College District, California
Former President, North Lake College, Texas

Preface

The papers in this monograph represent the award-winning concepts submitted in response to a call for meaningful ways to examine the latest in genetic research and related issues from the community college perspective. The Exxon Education Foundation provided North Lake College and the Dallas County Community College District with funding to hold a conference, *The Genetics Revolution: A Catalyst for Education and Public Policy*, and to provide awards of \$1,000 for each of 30 papers.

Potential contributors were asked to submit for a blind review a five-page outline of their plan to incorporate the scientific, technical, and public policy dimensions of genetic research and the Human Genome Project (HGP) into community college curricula. The papers, selected for Exxon Education Foundation Innovation Awards, do not represent the opinions of the Exxon Education Foundation or of any of the sponsoring organizations.

The winners made presentations at the conference, held in Dallas in March 1996. In addition, they heard many internationally known speakers discuss their own research and the ethical, legal, and social implications of the HGP. In the months that followed, those who had been chosen for the Innovation Awards then revised and expanded their papers to reflect the conference presentations and discussions. The papers are presented here.

This document is designed to inform the reader about the latest developments in genetics from many perspectives, to provide information and activities that can be taken into the classroom, and to stimulate thinking about programs and services that the community college can provide to inform its constituency about this important subject. The papers in this monograph have been edited for the following purposes: (1) a few represent media-based presentations that could not be effectively reproduced on paper, and (2) many replicated material covered in greater detail in other papers. Consequently, some of the replicated material was deleted. Some authors used the British spelling of scientific terms and some used the spelling more common in the United States. No attempt was made to reconcile these. Many new terms and expressions are being generated by the genetics revolution and are used by authors; for example, *bioethics*, *biotechnicians*, and *genetic counseling*.

There has been no attempt to establish consistent definitions for the purpose of this monograph.

Many papers included rationales for teaching about the HGP and about biotechnology and the implications for public policy and society. Although the papers have been edited to avoid repetition, the arguments are compelling and may be summarized as follows:

According to Charissa Urbano, "Today's students will live in an era influenced by the revolution in genetics and its emerging technology." But Joan McCoy-Messer pointed out that while many citizens will be involved in creating policy to govern the dilemmas created by the HGP, "most . . . have had little education in the molecular biology and biotechnology necessary to understand the issues." An important point made by many of the monograph authors is that the community college, which directly or indirectly touches the lives of so many, is the logical place for this education to occur. Allen Hunt stated, "Community colleges are the working class of higher education, the academic liaisons of the community, the bridge between ignorance and understanding." Ram Nayar pointed out that "a course which incorporates genetics with emphasis on the findings from the Human Genome Project . . . will help to create a citizenry that is both well informed and scientifically literate."

Summary

The main purpose of the conference was to create a core of community college leaders who were committed to developing meaningful ways to incorporate the scientific, technical, and public policy dimensions of genetic research and the Human Genome Project into their curricula. This monograph is a continuation of that effort and an attempt to educate college and community leaders in preparation for the emerging public policy issues and the role community colleges will play in providing forums that facilitate learning.

The call for proposals required that conference presentations and the resulting papers address one of the following issues: human genetics in the basic sciences, new technology in business and industry, and public policy education. The papers included here, many of which speak to more than one of the issues, have been organized into categories that lend themselves to integration into the community college curriculum. Some of the papers assume little prior knowledge of genetics or anything more than a layperson's familiarity with science.

Others provide some scientific background and then build on it. Still others are written for professional science educators who desire to develop new biotechnology programs, enhance existing programs, or just incorporate a current discussion of genetics issues into their courses. A brief explanation of the Human Genome Project is provided in the Introduction, and an overview of the history of genetics and the HGP is provided in more depth in chapter 8, "Educating the Educators: The Genetics Revolution in the Community College Setting."

Ethical, Legal, and Social Issues

The possibilities presented by genetically altering plants and animals, cloning of humans, and curing disease have come to the attention of the general public. Consequently, the ethical, legal, and social issues (ELSI) related to recent breakthroughs in genetics have become front-page news. Several papers focus on these aspects of the HGP.

In chapter 1, "Facing the Unknown: The Ethical Challenges of Biotechnology," the author argues on behalf of the engagement of the "imperative of the unknown" as part of making decisions about new technologies such as biotechnology. Chapters 3, 5, and 7, "The Genetics Revolution: Toward a Sense of Ownership," "The Third Genie: Genetic Considerations at the Community College Level," and "David's Dance: Historical Responses to Genetic Knowledge," address how society and culture have dealt with advances in science and the potential impact of educators, philosophers, and theologians on the scientific world. In chapter 2, "Disclosure of Genetic Information to Family Members: Ethical and Legal Implications," an attorney discusses the issues raised by the disclosure of the genetic makeup of a family member. A particular instance of this dilemma along with a consideration of the possibilities of genetically editing the human race is dramatized in the play *The Twilight of the Gods*, the subject of chapter 4. Chapter 6, "Bioethics in the Classroom," describes strategies for teaching genetic counseling and ethics in a nonmajors biology class.

Biology, Nursing, and Allied Health Courses

The genetics revolution has endless implications for teaching science, not only for those pursuing careers in science and the health sciences but for others who simply need to make educated decisions concerning public policy and the well-being of themselves and their families.

The papers in this section are written for a variety of audiences.

Chapter 8, "Educating the Educators: The Genetics Revolution in the Community College Setting," serves as a brief overview of the history of genetics and the Human Genome Project. Three papers are directed specifically to those interested in health care education. Chapter 9, "Field of Dreams—'Build It and They Will Come': Building a Program in Genetics at the Community College," describes the development of an articulation agreement with a four-year institution for students interested in careers in biotechnology, as well as conferences for professionals in those genetic careers. Chapter 12, "Incorporation of the Human Genome Project into a Human Genetics Course for Allied Health Fields," describes helping health care students to understand how new genetic information and technologies will influence medicine in a moral, ethical, and technical way. Chapter 13, "Integrating Genetic Knowledge into Community College Nursing Education," highlights the influence of genetics across the life span, in common diseases, and in drug therapy.

Chapter 10, "Chromosomes: Crucial Road Maps for Molecular Genetic Studies" provides a better understanding of genes and how to modify and insert them to refunction in live organisms. A specific application of gene modification, the production of transgenic crops, is discussed in chapter 11, "Transgenic Crops: New DNA in Your Food." The types of modifications being considered and the role of the community college in the surrounding debate are addressed.

Several papers provide laboratory exercises along with lists of necessary equipment and supplies. Chapter 14, "Introducing Concepts and Skills in DNA Technology," introduces students to spooling DNA, electrophoresis, and modeling gene cloning. An interactive approach to teaching the biology of DNA is described in chapter 16, "Multimedia Approach to DNA Teaching." This program utilizes an authoring program to which scanned figures, video captures, classical music, and art were added. Chapter 18, "A Combination of Laboratories in Biotechnology Demonstrating the General Approach of the Human Genome Project," presents details of learning experiments that incorporate articles familiar to students and that illustrate aspects of the HGP. The dynamics of gene expression and the technologies used to study the genome in vitro are discussed in chapter 19, "A Laboratory Approach to Molecular

Genetics as an Adjunct to a General Biology Sequence and Clinical Chemistry Course.” An interactive exercise on DNA fingerprinting is presented in chapter 20, “A DNA Fingerprinting Exercise for Any Type of Class.”

Some authors found that students discover the excitement of genetics through studying family pedigrees and patterns of inheritance. Field trips often make these explorations more meaningful. Chapter 15, “Human Genetics,” and chapter 17, “Discovering Genetics through Field Trips,” describe the authors’ teaching experiences.

Biotechnology Programs

The field of biotechnology holds promise of exciting careers for community college students. Four papers provide an overview of community college programs designed to prepare biotechnicians. Chapter 21, “An Interdisciplinary Approach to Genetics in a Biotechnology Program,” outlines the program at Middlesex Community College that simulates industrial practice. The report of a survey of the biotechnology industry on needed workforce skills is included in chapter 22, “Instilling Job Literacy for Current and Upcoming Biotechnology Occupations.”

Chapter 23, “Growing a Community College Biotechnology Program through Collaborative Partnerships,” discusses internships, mentorships, professional development, faculty fellowships, and other cooperative ventures with industry. San Diego City College is providing students with skills used in the industry by employing representatives from the biotechnology sector as instructors. Details can be found in chapter 24, “An Applied Biotechnology Capstone Course: Melding the Resources of the Community College and Industry.”

One college has focused on providing professional development for high school teachers in molecular biology and biotechnology. This program and their unique Mobile Biotechnology Laboratory are discussed in chapter 25, “Biotechnology at William Paterson College: Educating Students for the Genetics Revolution.”

Multidisciplinary Approaches

Aspects of the HGP have been integrated into courses involving many other relevant disciplines and thus providing exciting opportunities for learning. These experiences are offered in a variety of formats. Chapter 26, “A Multidisciplinary Approach to the Human Genome Project,” explores the HGP from the perspectives of

three very different academic disciplines: biology, philosophy, and psychology. Chapter 27, “Genes in the Making: Human Genetics for General Education in Community Colleges,” outlines a general education course dealing with classical and molecular genetics. Still another approach to the HGP is provided through a multimedia course in genetic principles and described in chapter 28, “Educational Catalysts and Their Implications.”

Chapter 29, “A Learning Community Biotechnology Curriculum,” presents a curriculum for health science majors which places the core concepts of general biology and sociology into a framework that emphasizes current issues in genetics and biotechnology. An exciting combination of biology, religion, European history, and an integrated study of genetics is described in chapter 30, “An Interdisciplinary Honors Course Explores the Scientific, Ethical, and Historical Aspects of Genetics.”

Educating the Community

The community college is integral to a democratic society; participatory government is valid only when decisions are informed. We hope this monograph will inform and inspire those involved with educating the community-at-large, degree-seeking students, or members of citizens’ groups, to provide an environment in which people can obtain information and reflect their concerns. North Lake College and the editor invite your comments and questions about the monograph or conference.

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Many people brought this idea to fruition. Jim Horton, at that time president of North Lake College, not only developed the concept for the project, he participated fully in its implementation, delaying his departure for a new position until its completion. The fact that the chancellor of the Dallas County Community College District and North Lake College vice presidents, Angie Runnels and John Tuohy, made the conference a high priority contributed greatly to its success. The college's new president, David England, has continued to support the dissemination phase through this monograph.

The Genetics Revolution Advisory Committee gave many hours and much creativity to the paper selection process and to the conference. The members of the committee deserve much of the credit for the success of the conference; they are Julia Sullivan, Pamela Ice, Phillip Shelp, Henry Su, Martha Hughes, William Slonecker, Gary Swaim, James Butzek, Robert Agnew, Patricia Corbett, and Shirley Thompson. Many thanks also to Caryn Korshin, at that time program officer at the Exxon Education Foundation. We are grateful to Julia Sullivan, who went beyond her role as North Lake College's public information director. The graphics departments at North Lake College and at Richland College offered their expertise. And, of course, many thanks to the Exxon Education Foundation for believing in us, to AACC for publishing the monograph, and to all the sponsoring organizations.

SPECIAL CONTRIBUTORS: Linda Washington served as secretary to the conference advisory committee, supervised numerous mailings, and provided considerable assistance with the preparation of the manuscript. Pamela Ice provided valuable advice on the conference and professional expertise in assisting with the planning and editing of the monograph.

Introduction: Status of the Human Genome Project

J. Craig Venter

The Institute for Genomic Research, Rockville, Maryland

The idea of sequencing the entire human genome was proposed in the mid-1980s. It was separated into three phases: the development of a physical and genetic map (phase 1), sequencing of the 3 billion base pairs of DNA that make up the human genome (phase 2), and analysis of the biological functions of the complete genomic sequences (phase 3), as an ongoing effort proceeding well into the 21st century. Sequencing of other model organisms was to be done simultaneously to obtain basic information about the biology of these organisms, for purposes of comparative genomics and to provide clues about how to diagnose, alleviate, or cure human disease. The National Institutes of Health's (NIH) Office of Human Genome Research, now known as the National Human Genome Research Institute (NHGRI), was established in the late 1980s. The Human Genome Project began in earnest about 1990 as an estimated 15-year enterprise for the sequencing and mapping phases.

There has been considerable progress since the start of the project, although not strictly along the route originally envisioned. The revised five-year plan issued in 1993 concluded that further technological development was necessary before genomic sequencing could begin, and the date for acquisition of a complete set of human genes was estimated to be after the year 2005. Meanwhile, as the world awaited technological breakthroughs in DNA sequencing technology, major funding would go to gene-mapping efforts.

It seemed to me that the estimated date of 2005, by which time a complete set of human genes was to be acquired from sequencing genomic DNA, was much too optimistic. At the then-prevalent levels of sequencing efficiency, it more likely would take decades to accomplish the goal. It also seemed that by the year 2005, if the world saw a great deal of mapping of relatively few genes

and saw even fewer practical results, funding for the Human Genome Project could easily dry up. It did not make sense to me that medical research should have to await what seemed like a rather vague and distant technological millennium before large numbers of human genes could be examined with an eye not only for medical diagnostic and therapeutic uses but also for what could be learned at the molecular level about evolution. Nor did it make sense that the great potential for human benefit to be derived from genomic research in plants, animals, microbes, and parasites should be held up because of the prevailing judgment that large-scale genomic sequencing of DNA was many years and a number of inventions away. These were the considerations that spurred me to search for another way.

In our work in human gene discovery at NIH and later at The Institute for Genomic Research (TIGR), we developed the cDNA/EST (complementary DNA/expressed sequence tag) approach, using bioinformatics to reassemble gene fragments into large assemblies and entire genes (Adams, et al., 1991). The results amazed even those of us who had great expectations for the approach. In a year and a half, we identified more than half of the estimated 70,000 human genes. *Nature* published a special supplement (Adams, et al., 1995), containing a paper by the TIGR team that includes the results of this human gene discovery effort. The EST approach is now generally followed by the DNA sequencing community, and ESTs from a wide variety of species now make up more than 72 percent of GenBank accessions, including ESTs representing more than 80 percent of all human genes.

The refinements in bioinformatics, sequencing technique, reagents, and human skills that came out of our human cDNA work convinced me that it would be feasible to sequence the genomic DNA of a microbe using the random sequencing method. Heretofore, it had been thought impossible to bring such a genome to closure using this technique. So we proceeded to sequence the genome of *Haemophilus influenzae*, the first free-living organism ever to be completed, and our team completed the task in a year (Fleischmann, et al., 1995).

Next, TIGR scientists completed sequencing the genome of *Mycoplasma genitalium* (Fraser, et al., 1995) and *Methanococcus jannaschii* (Bult, et al., 1996). *M. jannaschii* is a member of the Archaea, organisms that define a third branch of life and share at the molecular level properties of both the prokaryotes and the eukaryotes, the other two branches of life. With the sequencing of

M. jannaschii, scientists now have the opportunity to study at the genetic level a microbe that lives at 85 degrees C (185 degrees F); at a depth of 2,600 meters (1.65 miles); and under 260 atmospheres of pressure, which is a bit under two tons per square inch and enough to crush an ordinary submarine! Moreover, this microbe is an autotroph, metabolizing inorganic substance (hydrogen and carbon dioxide) and generating methane. Many of its enzymes will be studied for their use in high-temperature industrial and pharmaceutical processes, and its methane generation holds out prospects for future energy uses.

Since 1995, the sequencing of the genomes of small organisms has flourished. Twelve microbial genomes have been completely sequenced with another 30 or so close to completion (see www.tigr.org for a recent update). Included in the 12 sequenced genomes is that of the most important model bacterial organism, *Escherichia coli*, as well as the organisms causing ulcers (*Helicobacter pylori*), Lyme disease (*Borrelia burgdorferi*), and oil well "souring" (*Archeoglobus fulgidus*), the last three sequenced by TIGR. *Bacillus subtilis*—a member of the gram positive bacteria, which is important environmentally, industrially, and in medicine—recently has been sequenced by an international consortium. Several additional Archaeal organisms also have been added to the list of completely sequenced genomes. The long-term benefits to humanity from this microbial work will be many.

Our successful random sequencing of microbial genomes several megabases in size, particularly our development of the computer algorithms necessary to assem-

ble them, led us to use this strategy for sequencing human genomic DNA on a large scale, which is now under way in a dozen labs worldwide. Previously, the large-scale sequencing required for such a huge project was awaiting the introduction of major new sequencing technologies that did not, however, materialize. Our combination of automated DNA sequencers, random sequencing, and computer assembly of megabase-size pieces of DNA has become the world standard approach in the Human Genome Project. It is now expected that using this strategy, the project has a good chance of meeting a completion date in the first decade of the new millennium.

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PART I

Ethical, Legal, and Social Issues

1

Facing the Unknown: The Ethical Challenges of Biotechnology

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Abstract: This paper attempts to argue on behalf of the engagement of the “imperative of the unknown” as part of the decision-making process when it comes to new technologies such as biotechnology. Working from the Kantian categorical imperative and Hans Jonas’ reformulation in his Imperative of Responsibility, the author develops a new imperative that takes into account the dramatic increase of the domain of the unknown with regard to biotechnology.

Relevant discipline: philosophy

They do not, like the old, merely exert a gentle guidance over nature’s course, they have the power to conquer and subdue her, to shake her to her foundations.

—Francis Bacon

In the 17th century, when Francis Bacon wrote the above words, he could have no idea how prophetic they would become for the new biotechnological age. He tells us that nature must be “put into constraint, moulded, and made as it were new” (Bacon, in Spedding, Ellis, and Heath, 1870). With the exception of the splitting of the atom and the subsequent invention of the atom bomb, at no time in history has the human race had such power to take nature and “shake her to her foundations.” For Bacon and René Descartes it was a matter of both divine right and moral imperative that humanity instate itself as the “lords and possessors of nature” (Descartes’ famous phrase). Their intentions were among the loftiest ideals of humanism, namely to free humanity from its bondage to ignorance, sickness, and poverty, to liberate humanity from its enslavement to nature so that we might realize the higher goals for which we were divinely destined. We had been cast out of Eden, but there was a road back, a road built by human ingenuity, skill, rationality, and technology. Expressed here is an ethos, crystallized in such notions as “progress,” which says that anything we have the power to do, we have the right, indeed, even the duty, to do. The new biotechnological age continues this ethos, but genetic engineering would accomplish this by taking those foundations of nature and quite literally reinventing nature from the inside out.

We are entering into a new age, one that entails not only the wide-scale application of these new technologies but also new modes of understanding and organizing the world. As changes occur, we are faced with a situation best characterized by the ethics of the unknown. The ethics of the unknown is not a mandate to abandon all ethics but rather a call to a new type of ethics that results from a sensitivity to both the past and the future. The uncertainties about the *is* (the present and future facts) does not absolve us from certain *oughts*; rather such uncertainty should become the foundation upon which our *oughts* are based.

We have entered an age that is cybernetic and biotechnological. We have reached a paradigmatic turning point in the history of science and technology and thus a paradigmatic turning point in both human and natural

Table 1.1 Patterns of Understanding, Organization, and Practice

ORGANISTIC/ PREMODERN	MECHANISTIC/ MODERN	CYBERNETIC/ BIOTECHNICAL POSTMODERN
Vital force/energy	Matter/motion	Information
Participation	Representation	Simulation/programming
Correlative thinking	Causal thinking	Systems thinking
Holistic	Atomistic	Behavioristic
Monism/unity Continuity of being	Dualism Discontinuity of being	Pluralism Relationality of being
Whole to part	Part to whole	Reflexive within system or field
Cyclic time	Linear time	Virtual time
Tradition/Repetition	Innovation/Progress	Creation/neo-evolutionary
Dependence upon nature	Domination of nature	Reinvention of nature
Communal self	Individual self	Virtual self
Biological process seen as spiritual/ metaphysical	Biological process seen as physical/ mechanical	Biological process seen as inscribed/ signified/informational
Archaic technology	Pyrotechnology	Biotechnology/genetic engineering/cybernetics

history. This shift must be seen at the broadest philosophical and cultural level possible. Table 1.1 schematizes the general patterns of understanding, organization, and practice. The table can provide a useful reference point for what will be called the foreground and the background of biotechnology.

Biotechnology must be seen in the context of a worldview we term the "information age" or the "cybernetic age." This shift is one in which the world is literally reconceived in terms of information and systems of information exchange. Norbert Wiener's theories of information systems pertained not only to computers but to the biological world as well. He says that information "belongs among the great concepts of science such as matter, energy and electric charge" (Wiener, 1954). In a fundamental shift from either the premodern or modern periods, cybernetics is not concerned with what a thing is but how it behaves. Behavior is defined as the exchange and processing of information. It is in this sense that we can speak of new "ages" or "epistemes," the broad characteristics of which are listed in Table 1.1. The term *epistemes* is taken from the early work of Michel Foucault. It refers to the historical (social, political, intellectual) conditions under which certain truths and practices develop. While the modern physicist continues to look for the basic building blocks, the smallest particles, cybernetics sees the foundation in terms of information and information processes because these determine behavior. Thus, genetic engineering is not just the application of mechanical engineering to biological materials but a totally new way of understanding, ordering, and interacting with the world (Buchanan, in press).

As an example of the way in which different worldviews determine different social practices we might look briefly at the problem of conservation. Conservation is a discourse (and a practice) that can be constituted in any number of ways. Within the three models characterized in Table 1.1, we can see that along with conservation other key concepts such as "species" or "nature" itself are redefined. If we begin with the premodern/organistic model, conservation would be taken holistically. This approach defines a species in terms of the ecosystems within which it exists. Thus, the keys to survival and conservation are the preservation of the entire ecosystem. This approach is basic to the Convention on Biological Diversity negotiated by the United Nations Conference on Environment and Development (UNCED). Within a modern/mechanistic model a species is viewed atomistically. By this we mean that a particular species is

defined morphologically or in terms of its physiological traits. This physical approach emphasizes structural characteristics and is consistent with the modern concentration upon matter. Conservation has focused upon saving members (even to a single member) of a species in zoos; parks, both national and theme; and preserves or compounds. These may be attempts to recreate, save, or approximate the natural habitat in varying degrees, but the emphasis is not upon preservation of the ecosystem but upon individuals or members of those species. In a cybernetic/biotechnological model the preservation of species reinscribes conservation as the preservation of the genetic code. The context of conservation and preservation shifts from the ecosystem or zoo to the gene bank. Gene banks, both public and private, are being established all over the planet. When argued in isolation from the other options, it is easy to claim that we are saving a species from extinction if we save only its genetic code and to argue that this is "good." But what must be recognized is that in so arguing we have redefined *species* in terms of a new information-based worldview.

Biotechnology and the Bioindustry

Biotechnology is different from most new sciences in that it has been developed primarily as an industry. This means that the diverse motivations of pure science and those of business are constantly being mixed together. *Bioindustry* is a term used collectively by those engaged in the commercialization of genetic engineering. Because of the rapidity of privatization of biotechnological science, the bioindustry has been forced to place undue emphasis upon promises and foregrounding. Publicly funded research can be carried out without undue emphasis upon foregrounding and promises. The disturbing fact that a disproportionate number of scientists involved in genetic research are directly or indirectly affiliated with the bioindustry means that economic interests play a large role in presenting the case for biotechnology as well as in determining the direction of its development (Krimsky, 1991; Kenney, 1986).

There are two issues here. First is the background issue concerning the proper role of university research and of university scientists. This involves issues ranging from possible conflicts of interest to the privatization of knowledge, which was previously circulated freely among researchers, to the control of the direction of research by commercial concerns. Second is the foreground issue—the degree to which the bioindustry has been built upon

promise and speculation. Firms such as Genetech, Biogen, Repligen, and ImClone have all raised much of their capital not upon actual products but upon the promise of products. The degree to which this has occurred is unprecedented in business history. *Genetic Engineering News*, the periodical with the widest circulation in the industry, appears to be dedicated to foregrounding. Likewise, the industry has shown itself to be very effective in its use of the news media. Hardly a week goes by that we do not see or read a report of the latest breakthrough in genetic engineering.

The point is not to deny the real and potential contributions of genetic engineering but to argue that a disproportionate amount of money is spent on foregrounding. It has been estimated that the major U.S. biotechnology companies spend up to 25 percent of their income on marketing and that up to 30 million visits are made by salespeople to doctor's offices per year (Abelson, 1992). Such massive efforts to keep the public's eye on the prize tends to obscure the background issues. Even governments are engaged in such hyperbolic foregrounding. During the Reagan and Bush administrations it was believed that the long-term economic survival of the United States was directly tied to the development of biotechnology. Forecasts have been made that by the mid-21st century between 60 and 70 percent of the gross national product of the United States will be directly or indirectly tied to biotechnology. The Clinton administration is doing everything within its power to foster the development of the bioindustry.

As biotechnology is privatized, as it becomes increasingly a bioindustry, there will be less and less attention given to background issues because such "diversions" can only serve to impede "progress": the technological imperative and the pressing need to bring products to market in order to secure return on development costs. The contributions to health, agriculture, and the economy are unknown. While this is nothing unusual for research, in this case the promise of a product is marketed as if it were accomplished fact.

The Eugenics Question

An ethical question of biotechnology that frequently is avoided is the issue of eugenics. Eugenics is the systematic attempt to create more perfect humans by means of controlling genetic material. The term itself is explosive because of the Nazis' World War II programs of eugenics in which they sought to create a purified Aryan race.

Biotechnology opens up a new era of eugenics. We can speak in terms of positive and negative eugenics. An example of negative eugenics is the use of genetic therapies to remove genetically inherited diseases and to eliminate characteristics that are considered bad. Positive eugenics would be the reengineering of traits not because they are bad but because we, individually or as a group, consider them good. For example, if blue eyes were considered more beautiful than other colors there might be attempts to genetically alter humans toward this end. Most find negative eugenics acceptable but see positive eugenics as more problematic. Where do we draw the line between "bad," or "disease," and good? *Disease* is a term that we apply to a wide range of phenomena determined by changing political, social, philosophical, religious, and economic climates. While we might all accept Huntington's as a disease, alcoholism or other problems of substance abuse are more controversial.

Eugenics is the promise of future perfection. But the background issue is that of competing goods. Shall we let the good be determined by consensus? Or shall we let the invisible hand of the marketplace determine what is and is not good? Models of good and of perfection vary widely and change over time. The other side of this is the argument that the strength of humanity and of nature in general is in diversity. Genetically imposed models of perfection will tend toward monoculture, and in the end monoculture and what Vandana Shiva calls "monoculture of the mind" (Shiva, 1993) may be greater threats than the diseases and imperfections we eliminate. Two examples will serve to make this point. Currently, genetically engineered growth hormone is being administered to children in the United States not because they suffer from dwarfism or any form of dramatic height limitation but because they are shorter than "normal" for their ages. Do we begin to genetically normalize everyone? Who will determine what the limits of toleration for normal are?

Stephen Hawking, who has severe physical limitations as a result of Lou Gehrig's disease, is a second example of the conflicting goods of eugenics. One might wonder if there is a relationship between the limitations with which he lives and the seemingly unlimited expansiveness of his mind. He has said that given the nature of his work and the kind of support he has received from friends and family, that his disabilities have not been a serious handicap. He is a recent example of a long history of figures who have suffered from debilitating disease but have contributed

works of genius to human culture. If we eliminate the disease, does this affect the genius?

Biotechnology and the Environment

The term *eugenics* has been limited to human manipulation of the gene pool; it is not usually applied to nature or the environment. The term was coined in 1883 by Francis Galton, who intended it to refer both to the “science of improving stock” and to humans “to give the more suitable strains of blood a better chance of prevailing speedily over the less suitable.” (Galton, 1883). Its use has been restricted primarily to humans, but can we not speak in terms of environmental eugenics?

With biotechnology, nature and organisms become potential “biotechnological factories” because the technological processes are taking place biologically. In the past we built factories within ecosystems, having an impact on the environment. In the age of biotechnology the ecosystems themselves are reengineered to become the factories.

We already know that the impact of new technology on nature can be dramatic. Biotechnology, rewriting the codes of life itself, is an even greater threat. For example, consider the issues connected to the release of genetically modified organisms (GMO) into the environment. The release of a GMO is not like “normal” pollution such as an oil slick. Eventually, we, with nature’s help, can clean up an oil slick even though full restoration may take generations. Releasing a GMO into an ecosystem begins a new chapter in the natural (or maybe, now, unnatural) history of that system. Many of our ecosystems already are suffering undue stress because of declines in existing biodiversity and carrying capacity, and the release of new life forms could only exacerbate this situation.

Many developing nations have no laws regulating the release of GMOs. Will these countries become experimental dumping grounds for the bioindustry? Will we end up with “laboratorially advantaged” life forms that will overwhelm indigenous species? Will the biodiversity of the future be primarily that which comes out of the biotechnology labs? Effective scientific predictive ecologies are needed to ascertain the long-term impact of GMOs on ecosystems.

Intellectual Property Rights

As we enter into the information age, there is no more contentious area of legal studies than that of intellectual property rights. Information can be owned, and the deoxyribonucleic acid (DNA) chain is encoded information. Some of the issues connected to intellectual property rights can be brought to light by looking at actual cases.

The Human Genome Project is attempting to sequence the human genome. As sequences and partial sequences are discovered, the National Institutes of Health applies for patents on those sequences. This raises the question of who owns our genetic structure, both as a species and as individuals. The issue of individual ownership is raised by a case involving a man named John Moore.

In the mid-1970s, Moore entered the UCLA hospital and was diagnosed as having leukemia, which among other things required that his spleen be removed. The medical team discovered that Moore’s spleen was capable of producing a remarkable blood protein. The research team saved part of his spleen and developed a cell line from Moore’s T lymphocytes. The University of California regents filed for and received a patent on this cell line. They believed that the cell line could produce commercially valuable antibacterial and cancer-fighting drugs. Partnerships were entered into with Genetics, Inc., and various divisions of Sandoz, the Swiss-based pharmaceutical giant. Estimates of the cell line’s ultimate value are as high as \$3 billion. John Moore was told none of this. When he eventually found out, he went to court demanding a share of any profits. His case was thrown out in the lower courts, as it was determined that Moore had no proprietary rights over discarded tissue or genetic structure and that it had no identifiable economic value when in his possession. On appeal it was determined that he did have rights and was entitled to partial ownership of the patented cell line. The case eventually went to the California Supreme Court, which ruled that Moore did not have proprietary rights over his own genetic structure. The implications of this case legitimize the ownership of tissues, cells, and genes by patent holders. (Kimbrell, 1993; Mooney, 1991). The broader implications of this are expressed in the dissenting opinion of the Moore decision: “Far from elevating these biological materials above the marketplace, the majority’s holding simply bars plaintiff, the source of the cells, from obtaining the benefit of the cells’ value, but permits defendants, who allegedly obtained the cells from plaintiff by improper means, to

retain and exploit the full economic value of their ill-gotten gains free of . . . liability" (Kimbrell, 1993).

What are the long-term implications of patenting genetic materials? Must we file for patents on our own genetic structure in order to protect it? Are patents that are in principle global monopolies the best mechanism of ownership for genetic materials? How much are we obscuring the very complex ethical, social, and even religious questions and allowing foregrounding, the development of commodities within the marketplace, to determine the parameters of these issues? (Buchanan, in press).

Conclusion

Virtually all of the accomplishments or promises of future accomplishments in biotechnology are presented in ethical terms. Thus, the foregrounding of biotechnology is not just about the commodities it will provide but about the goods provided by those commodities. Such things as better health, better food production, and new techniques to clean up the environment are for the betterment of the world. Cogent ethical arguments can be mounted both for and against biotechnology.

Two things emerge clearly from our considerations. First, biotechnology represents a major shift in the direction of contemporary society, both in modes of understanding and practice. Such major shifts demand that we consider our past again to see what we might learn and that we rethink those principles that might have been appropriate for prior contexts but that might not be adequate to the current situation. Second, when it comes to the implications and long-term effects of biotechnology, we have entered a realm characterized by the unknown.

Denying the unknown a prominent place in our judgments and decision making about biotechnology is to deny one of the few aspects about which everyone agrees. The presence of the unknown reduces our ability to find simple, clear answers or to make quick, expedient decisions about biotechnology, but it is clear that too much is at stake to choose the least complicated path.

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2

Disclosure of Genetic Information to Family Members: Ethical and Legal Implications

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Abstract: Many ethical and legal issues surround the advances in medical genetics. The ethical and legal issues surrounding the disclosure of a family member's or another individual's genetic makeup are put forth in two scenarios. Students in an introductory genetics course should explore their own beliefs regarding the balance of privacy and information interests.

Relevant disciplines: genetics, ethics, law, philosophy

Introduction

The legal and ethical implications of new genetic discoveries should be introduced early in an introductory genetics course and reintroduced throughout the semester. Unlike more complicated genetic concepts, legal and ethical issues can be comprehended without a vast knowledge of genetics. Questions such as the right of the government to maintain genetic data banks or the decision to find out if an individual will develop an incapacitating disease in the future are issues posed at a very basic level. People have gut reactions to these questions, and when these matters are introduced early, a student becomes motivated to learn more about genetics.

Overview of Ethics and the Law

Ethics and the law are two different frameworks that prescribe behavior in a society. Ethics, or morality, is the study of right and wrong and good and bad as they apply to the actions and character of individuals, institutions, and society. Law is a body of rules of action or conduct prescribed by a controlling authority and having binding legal force.

Ethics and law are distinguishable. For example, the ethical rules of a society do not necessarily result in punishment if you break them, but the law does punish people who fail to meet its standard. Another difference is that the law gives clearer direction as to what is right or wrong than ethics. Ethical guidelines can be ambiguous; the law is not. Ethics and the law are distinguishable in that the law in many countries evolves through a defined structure of government. In this country that structure involves court opinions by judges and statutes written by legislators who are elected by the people. Ethics evolves through reflections by people using written histories and oral traditions.

Sometimes the boundary between ethics and the law appears to disappear because both fields may use the same vocabulary. For example, both law and ethics concern "rights" (Capron, 1973). When lawyers discuss rights they mean power, privilege, or immunity guaranteed under the constitution, a statute, or a decision by a judge. An ethicist approaches rights as power or privilege inherent in or granted to a person and consistent with the principles of morals.

Rights, whether they are legal or moral, are not absolute. One has a right to free speech but does not have a right to shout "Fire!" in a crowded movie theater if

there is no fire. Often, rights come in pairs; one individual's right is opposed by another individual's right. For example, the right of a mentally deranged patient to expect confidentiality from his physician regarding his threats to kill another person is balanced by the right of society to be warned of dangerous persons. In genetics, an individual's right to privacy about his genetic information is in opposition to family members' rights to genetic information affecting them. When a court is faced with competing rights, it must balance the interests on both sides to come to a reasoned answer.

Why Is There Interest in Knowing a Relative's Genetic Makeup?

A person has a stake in knowing the genetic constitution of his or her relatives, in order to obtain information for reproductive decision making and presymptomatic illness diagnosis (see Table 2.1). The interest an individual has in knowing a relative's genetic makeup goes beyond that of the immediate family. Knowing that a cousin is the parent of a baby with a recessive disease, such as cystic fibrosis or Tay-Sachs disease, alerts an individual that

he or she too may be a carrier for the recessive disease because cousins share genes. The probability is 6.25 percent, or 1/16, that two cousins share a particular gene.

It also is important to know whether a relative is symptomatic for an inherited adult-onset disease. Knowing that a parent or a sibling suffers from a dominant disease such as Huntington's disease alerts a person that he or she has a 50 percent probability of inheriting the disease. The person can choose to be tested for Huntington's disease and know whether the gene is present or not. Some will forgo testing and the certainty that the results bring in fear of receiving bad news, but at least the tested individuals can plan their future with the information that they do have.

Today, many of the diagnostic tests for genetic diseases require that whole families have their DNA studied even if only one individual in the family is interested in the predictive test. These studies involve closely linked polymorphic DNA markers. The DNA pattern from nuclear and collateral family members is crucial to the success of these genetic linkage studies, in which genetic information from many family members is required to detect the inheritance pattern of the disease. The cooper-

Table 2.1 Concerns Related to Information of a Relative's Genetic Makeup

CONCERN	EXAMPLE
A. Interest in knowing that a relative is a carrier of a recessive disease.	Knowing that a cousin gave birth to a baby with Tay-Sachs disease alerts a person to be tested for carrier status and, if positive, to take preventive measures such as prenatal diagnosis.
B. Interest in knowing that a relative is symptomatic for an adult-onset disease.	Knowing that a parent is suffering from Huntington's disease alerts a person to be tested for the disease or to plan life knowing that he or she has a 50 percent chance of suffering from the disease in the future.
C. Interest in knowing a relative's DNA status.	Genetic information from relatives is crucial to the success of genetic linkage studies that may need many family members to detect the inheritance pattern of the disease.
D. Interest in knowing the immunological genes that a relative possesses.	A person who needs a kidney or bone marrow transplant needs a donor who is as genetically compatible as possible. Because family members share copies of the same genes, there is a higher probability of finding a good immunological match within the family.
E. Interest in knowing a birth parent's genetic makeup.	A child is a product of adoption, artificial insemination, or gamete donation and does not know his or her genetic history.
F. Interest in knowing a spouse's genetic makeup.	Allows informed reproductive decisions.

ation of family members and access to their DNA is the linchpin of these studies.

Families also are important in tissue and organ transplants. The donor and the recipient in a transplant must be as immunologically compatible as possible. Immunologic compatibility depends on the human leucocyte antigen (HLA) genetic system. Although two unrelated individuals could be a perfect match immunologically (i.e., have the same HLA genes), the probability of this happening is very low because there are many combinations of HLA genes. An individual has the best odds of finding a good match within his or her family.

Other situations often exist in which it is important to know genetic information about one's relatives. Children who are adopted or products of gamete (eggs or sperm) donation may not have access to knowledge about their biological relatives. While they or their parents may be given a family history of the birth mother or the sperm donor, this is not the same as being able to test family members for genetic diseases. Adopted children or children who are products of gamete donation have a gap in their genetic history that cannot be filled without finding the biological parents.

Individuals have an interest in knowing the genetic makeup of their spouses or partners because this information may lead to making more informed reproductive decisions. Knowing that one spouse is a carrier for a recessive genetic disease, such as cystic fibrosis, may encourage the other to be tested for carrier status also. Or, it might persuade the couple to test their fetus for the disease or use a gamete donor.

Obviously, there are many reasons a relative would want or need information about another relative's genetic makeup. Do family members have a legal obligation to share their genetic information with other family members? Do family members have a moral obligation to share genetic information? Do their relatives have a legal or moral right to the information? Does a physician have a legal or moral duty to inform family members of a hereditary trait in the family if by doing so the physician discloses private genetic information about one of the family members?

Ethical Issues Surrounding the Disclosure of an Individual's Genetic Makeup

Ethical issues are raised in the classroom by considerations of disclosure of private genetic information about an individual to family members. Arguments can be

made both for disclosing and for not disclosing. Ethical dilemmas can be approached from either a rights-based view or a needs-based view. In consideration of these issues, two words should be defined: *privacy* and *confidentiality*. Privacy is an individual's right to limit information about oneself; confidentiality is the duty of someone, such as a physician, to restrict the information flow about a person.

A Rights-Based Approach

A rights-based approach begins with the presumption that because of the physician-patient relationship, patients can trust their doctors not to disclose private information to anyone. In 1990, the American Medical Association updated its Code of Ethics and discussed the right of confidentiality:

The patient has the right to confidentiality. The physician should not reveal confidential communications or information without the consent of the patient unless provided for by law or by the need to protect the welfare of the individual or the public interest (American Medical Association Council, 1996–1997).

This code of ethics does not speak of an absolute right of confidentiality. There are exceptions, such as the legal requirements to report gunshot wounds, infectious disease, and child abuse. In this way, the American Medical Association is balancing a patient's right to privacy with a right of the community to protect the public.

Perhaps if people know they have a genetic disease, their right to privacy about that disease must be balanced by other family members' right to know information that may affect them. Can the argument be made that if people reproduce and pass on their genetic makeup, they have an obligation to their descendants to inform them about genetic diseases?

A Needs-Based Approach

A needs-based approach is another way to deal with the ethical dilemma concerning disclosure of genetic information to relatives. This approach is advocated by bioethicists Dorothy Wertz and John Fletcher for resolving dilemmas in medical genetics. They argue that "the very nature of genetic information, as something that is shared among family members, goes against the grain of a rights-based approach." (Fletcher and Wertz, 1991). Wertz and Fletcher see the family rather than the individual as the patient. For example,

in molecular genetic disease diagnosis, there is a need for a family member and a physician to have access to the genetic information of other family members.

Wertz and Fletcher believe that their needs-based, or “ethics of care,” approach is preferred to the rights-based approach because the weak or innocent (those with fewer rights or no rights) are protected and patients are treated as members of a family rather than isolated persons. Many medical genetics decisions are family decisions. Wertz and Fletcher believe that family members will act benevolently toward one another without the need to invoke rights.

Legal Issues Surrounding the Disclosure of an Individual’s Genetic Makeup

Is there ever a legal duty to disclose personal genetic information to a family member? Two legal cases shed light on this question.

Tarasoff v. Regents of the University of California

Tarasoff v. Regents of the University of California is a 1976 California Supreme Court case that discusses the duty of a psychologist to warn third parties of serious danger. Prosenjit Poddar killed Tatiana Tarasoff on October 27, 1969. Her parents alleged that two months earlier Poddar had told his psychologist that he intended to kill Tatiana. Although Poddar shared an apartment with Tatiana’s brother, no one warned the Tarasoffs of Tatiana’s danger. After Tatiana’s murder, the Tarasoffs sued the psychologist, who was employed by the University of California, alleging that there was a duty to warn third parties of a danger to them. The California Supreme Court agreed with the Tarasoffs that the psychologist did have a duty to warn a potential victim of serious danger caused by his patient. The court held that since the therapist knew that Poddar intended to kill Tatiana, he incurred a duty to use reasonable care to protect the intended victim against such danger. What the therapist does to protect the intended victim depends on the nature of the case. He can warn the intended victim of the danger, notify the police, or take whatever steps are necessary.

This was a groundbreaking case because the court believed that there was a special relationship between the psychologist and Tatiana even though Tatiana was not his patient. Although Poddar and the psychologist had a physician-patient relationship and their communications were confidential, this right that Poddar had to confi-

dentiality was outweighed by the psychologist’s duty to Tatiana. Disclosure of information obtained in a confidential psychological session was essential to avert danger to a third party. As one of the justices said, “The protective privilege ends where the public peril begins.”

Precedent and the Law

The court system is based on precedent; case decisions are based on principles established in prior cases. When there is a case of first impression (a question that has not been answered before in the jurisdiction) and a judge needs to determine how to rule, the judge often will use a similar case as an analogy. Courts only are bound to follow precedents set in their jurisdiction—for example, only the California courts are required to accept *Tarasoff* as precedent for similar cases. But, courts in one jurisdiction may find cases in other jurisdictions persuasive and copy the legal reasoning when they are faced with a similar case. *Tarasoff* is a case in which a psychologist was found to have a duty to disclose a confidential statement to a third party to warn her of the danger posed by his patient. How might a court rule when deciding the question of whether a physician had a duty to disclose genetic information about his patient to a third party to warn of the danger a hereditary disease poses?

Pate v. Threlkel

The Florida Supreme Court recently considered the issue of whether a physician owes a duty to the children of a patient with a genetic disease. In *Pate v. Threlkel* (1995), the court considered whether a physician has a duty to warn the patient of the hereditary nature of his disease so that his children may be tested for the disease. In March 1987, Marianne New received treatment for a genetic disease called medullary thyroid cancer. Three years later, Heidi Pate, Marianne New’s adult daughter, learned that she also had medullary thyroid cancer.

The daughter filed a medical malpractice suit against her mother’s physician, Dr. James Threlkel, a cardiovascular surgeon. Heidi Pate alleged that because of the negligence of Dr. Threlkel she suffered from an advanced case of medullary thyroid carcinoma. She was not charging that Dr. Threlkel caused the disease because, after all, it was a genetic condition. But Heidi Pate believed that had Dr. Threlkel warned her mother that her children should be tested for the disease, she (Heidi) would have received a diagnosis of her carcinoma at an earlier stage.

Similarity between Pate and Other "Duty to Warn" Cases

The facts in *Pate* are a little different from the facts in the *Tarasoff* case, but there are similarities. *Tarasoff* and *Pate* share the question of whether there is a duty owed by a health care provider to someone who is not a patient. It is crucial to determine if a duty is owed, because in a medical malpractice case, it must be proved that a duty was owed and then that the duty was breached. Of course, even if the facts in the two cases were identical, the Florida Supreme Court would not be bound to follow the *Tarasoff* ruling because only courts in California must follow *Tarasoff*. However, the Florida Supreme Court justices knew about *Tarasoff* and could follow the case if they chose.

Heidi Pate's attorney cited two lower court Florida cases that found a physician owed a duty of care to family members and the public at large when contagious diseases are involved. In one case, a child who had contracted tuberculosis from her father sued her father's physician for medical malpractice because he did not diagnose the disease in a timely fashion. The court held that if minor children were in the family, the physician owed a duty to inform those in charge of the children of measures to be taken to prevent the children from contracting the disease. In another case, the court found that the physician owed a duty of care to hospital roommates. If one roommate suffers a highly contagious disease, the physician must warn the other roommate of the nature of the disease to prevent the spread of the disease. These two cases appear similar to the *Pate* case because an analogy can be made between infectious diseases and genetic diseases.

Is There a Duty to Disclose Genetic Information to Family Members?

The Florida Supreme Court held that Dr. Threlkel had a duty to warn of a genetic disease and that he owed a duty to the patient's children even if there had been no previous relationship between the physician and the children. But the duty could be discharged by warning the patient; it was not necessary to warn the children. This way physician-patient confidentiality is not breached. The court held that the patient ordinarily can be expected to pass on the warning. The physician was not required to find and warn other family members. It was thought that requiring the physician to find and warn other family members would be too great a burden for the physician

because of the difficulty and impracticality of the task. However, the court did not address the situation in which family members have the same physician and the finding and warning of other family members would not be a logistic problem.

By ruling as it did, the Florida Supreme Court attempted to balance the right to privacy a patient has regarding his medical records with the right of other family members to learn about the family's genetic inheritance. The court did this by placing the duty to disclose the information to family members on the patient. How realistic is this? Can the patient always be expected to disclose information about his medical condition to family members? Family members may have a moral obligation to share genetic information, but they do not have a legal obligation.

Discrepancy between Ethical and Legal Views on Disclosure

In 1983, the President's Commission for the Study in Ethical Problems in Medicine recommended that disclosure of medical information to family members should be made by a physician only if all of the following requirements are met:

- ◆ Reasonable attempts to elicit voluntary disclosure are unsuccessful.
- ◆ There is a high probability of harm to an identifiable third party.
- ◆ There is reason to believe that disclosure of the information will prevent harm.
- ◆ The disclosure is limited to the information necessary for diagnosis or treatment of the third party.

These ethical guidelines do not agree with the law. At the present time in most states, a physician would be legally liable for improperly disclosing confidential medical information unless the disclosure is allowed by statute.

In 1989, Fletcher and Wertz published the results of an international study of M.D. and Ph.D. medical geneticists. They gave the medical geneticists a scenario to consider in which a family member carrying a mutant gene, like the one for Huntington's disease, refused to permit disclosure of the diagnosis to relatives who were at risk. More than half of the medical geneticists said they would breach confidentiality and warn relatives over the patient's refusal. Approximately a quarter of them would tell the family members even if

they did not seek out the information. And the medical geneticists were equally likely to tell relatives about an untreatable disease as a treatable disease. (References and related readings by these authors for the international study are provided.) A great discrepancy exists between what the law says about the disclosure of genetic information and what the medical geneticists say they would do regarding the disclosure of genetic information. Should there be legal protections for geneticists who breach confidentially to warn family members at high risk for genetic disease?

Ethical and Legal Analysis of Two “Duty to Disclose” Genetic Information Scenarios

The ethical and legal implications of the following two scenarios can be considered by students with little knowledge of genetics; consequently they can be used to motivate the study of genetics.

Scenario One

A 55-year-old man does not want the fact that he has Huntington’s disease disclosed to his immediate family, from whom he is estranged. Huntington’s disease is a neurodegenerative disorder that is characterized by motor disturbances, loss of cognitive functions, and psychiatric manifestations. It is an inherited adult-onset dementia that will, on average, affect 50 percent of the affected individual’s children. His children, who are in their 20s and have not yet had children of their own, do not know that they may be carrying the gene for Huntington’s disease. A diagnostic test for Huntington’s disease is available and can detect the presence of the gene before the person has symptoms of the disease.

Issues to be considered in the discussion of scenario one:

- ◆ To whom does the physician owe the greater duty, the patient who wants the diagnosis kept confidential, or the patient’s children who are young adults and who should have the information disclosed so that they can make informed choices about their own lives?
- ◆ By making the decision to reproduce, do people incur an obligation to disclose any information about their genes to their children? Should access to genetic testing be made conditional on prior agreement to disclose information to other at-risk relatives?

- ◆ Does the severity of Huntington’s disease influence the physician’s decision?
- ◆ Does the timing of the disease (i.e., late adulthood) influence the physician’s decision?
- ◆ Does the fact that Huntington’s disease is currently untreatable influence the physician’s decision?
- ◆ Would it make a difference in the physician’s decision if the children knew that Huntington’s disease was already being inherited in their family?

Scenario Two

A 25-year-old woman comes to her physician for infertility problems. She is diagnosed as having testicular feminization syndrome, a rare inherited form of male pseudohermaphroditism. She does not want her husband told the reason for her infertility; she is emotionally distraught over the diagnosis. Persons with this syndrome have a male chromosome constitution (i.e., XY), but because of androgen insensitivity their outward appearance is female. It is not possible for people with this syndrome to have children because neither their male nor female reproductive organs are fully developed. Persons with the syndrome are at an increased risk of gonadal cancer. Testicular feminization is an X-linked syndrome, and the genetic sisters of a person with the syndrome have a 50 percent chance of being carriers of the syndrome.

Issues to be considered in the discussion of scenario two:

- ◆ Does the physician have an obligation to inform the husband over the wife’s objections so that he can make informed procreative decisions?
- ◆ Should the physician tell the woman she is sterile, but not the true reason why, because of the emotional damage the knowledge will impart?
- ◆ Does the fact that testicular feminization syndrome is not a fatal diagnosis influence the physician’s decision?
- ◆ Does the fact that the husband and wife are not genetically related influence the physician’s decision?
- ◆ Should the sisters of the woman be informed of the diagnosis, since they may be carriers of testicular feminization?

Conclusion

Issues related to disclosure of genetic information to family members can be introduced early in an introductory genetics course with any necessary information on genetics being introduced concurrently. Understanding the significance of genetics in their own lives will motivate students in their study of this rapidly evolving science.

Acknowledgments

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3

The Genetics Revolution: Toward a Sense of Ownership

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Abstract: Educators, philosophers, and theologians were once guardians of morality and society. The well-educated public will see these professions less as guardians and more as catalysts challenging people to engage in dialogue about what it means to be human in today's scientific and technological world. This dialogue must address the genetics revolution.

Relevant disciplines: philosophy, ethics

Prelude

In his poem "Pied Beauty," Gerard Manley Hopkins asks that "Glory be to God for dappled things. He fathers forth whose beauty is past change. Praise Him." The fathering forth continues. Will the genetics revolution be found among the dappled things so fathered, "sweet, sour, adazzle, dim"? Can it be said that the genetics revolution was on God's mind from the beginning, "counter, original, spare, strange"? If so, then, when the Original Man and the Original Woman first tried to heal each other's bodies, perhaps as simple a thing to us as a splinter in a finger, the genetics revolution was on its way. God creating, humanity co-creating, the genetics revolution may very well be healing at its highest level. All humanity stands to gain. Therefore, all humanity must be involved. The genetics revolution must not merely happen to people. People must be partners to it because it is too large and personal and all-embracing to be treated otherwise.

The two words, genetics revolution, joined, are loaded with nuance. In his book *Slavery and Freedom*, in the essay "The Lure of War," Nikolai Berdyaev reflects upon a curiosity, what he calls an astounding thing. Many Christians, he says, reject revolution with horror, but they accept and even bestow their blessing upon war. He says this is because values are determined according to a different standard. When state and nationality are highly valued, for their own sake, we might kill and shed blood to maintain the status quo. When freedom and justice are higher values, they challenge the status quo, and values once considered hard and strong may change. The word *revolution* signifies change in a profound sense. The genetics revolution signifies profound change—change in the way women and men imagine themselves, change in the way they imagine the world, change in the way they imagine God.

What is imagined is fraught with risk. The entire human enterprise, including the genetics revolution, is a risk. Perfect, it is not. Nobel laureate Baruch Blumberg must have considered this when he said that successful engineers and other applied scientists are practical and will not allow the perfect to drive away the good. This is a source of relief. Women and men will do the very best they can, as they always have.

When imagining God, it will be important to imagine God as intimately involved in change. Otherwise, the talk will stop before it starts, and we need a dialogue. A dialogue involving the genetics revolution and current

theology will help initiate and sustain a much-needed sense of ownership among diverse peoples of faith. Though it is not a novel idea to say that God cares, it may be a novel idea to say that God is interested in all that women and men do. No longer imagining God as against change, theology will be liberated to engage itself in an immense, ongoing, and worthy conversation.

In such a conversation, the roles of the professional educator, philosopher, theologian, sociologist, and psychologist are dramatically changed. They used to be the guardians of human morality and social structures, and while some may still see themselves that way, the well-educated public will see these professions less as depositories of values and tradition and more as catalysts. As catalysts, they can challenge people everywhere to reach into the depths of their own being and discover there what it might mean to be a human being in today's scientific and technological world. To catalyze is to raise questions provocative of dialogue. In dialogue we may learn to cope with our expanding technology, directing it in fruitful paths. This dialogue must address the genetics revolution. The community college, at the academic crossroads of America, is an ideal place for such a dialogue.

Theology and Science in the Past: The World-Denying View

It is important to know some history of the apparent conflict between Christianity and the world in order to understand better the need to reimagine God's role in human affairs. As long as the severe battle lines are drawn, science and religion will not hold a dialogue and God can only be imagined as saying "No." If religion and the world are at odds, science and religion are at odds. They need not be at odds. God can be imagined as saying "Yes." Since Christianity has influenced concepts of the world in the West, a peek at the ways the Church has imagined the world is in order.

The past reflects a view of the world and of Christian society in which there was no hope in this world. Christian society was a world-denying society, and monks were its professional world deniers. The world was radically evil and doomed to hell, and though this world was potentially saved by the cross of Christ, it was marking time until everyone could hear the message of salvation. Meanwhile, men and women had to strictly discipline themselves and one another because they were basically evil. Freedom was too dangerous, obedi-

ence to the Church was necessary to keep corrupt human nature out of mischief. Hardly a worldview that would encourage and nourish what we now understand by the scientific method. It would seem difficult even for a thoroughly modern pope to pull away totally from this worldview, although one can detect that he is trying. On October 6, 1995, in New York, Pope John Paul II remarked, "The magnificent scientific and technological civilization of which America is proud" must not ignore religion. This represents a significant leap toward world affirmation. Perhaps another pope will say that religion must not ignore the magnificent scientific and technological civilization of which America is proud. Worldviews affect world affirmation or world denial. Let us take a brief look at these shifts as they have developed in Christianity.

In the first century, the Church's attitude toward the world was, "Let the world come to us." Then, between the time she left the synagogues under Paul's influence and the time of her freedom in the fourth century, persecution time, the early Church's attitude toward the world was, "Let us wait on the edge of the concerns of the world." From the fourth century until the time of Hildebrand, who reigned as Pope St. Gregory VII, from 1073 to 1085, the Church's attitude toward the world was, "Take over the world. Shape the world into the Church." Of course, this did not work. From the time of Hildebrand, for about the next 500 years, the Church's attitude toward the world was, "Make the Church its own world." This worked well until the time of the Inquisition and the Protestant Reformation. As the scientific worldview asserted itself, people began to read and learn and question and doubt.

Then the inevitable happened. The Church began to see itself as above the world. The result? For the past 500 years the Church has gone its own way. The Church condemned modernism toward the end of the 19th and the start of the 20th century, and the world responded by building a world without the Church in it.

Then came Vatican II and a new view of the Church and the world: "The Church and the world are not at odds, nor are they competing. The Church is leaven in the world." This represented a significant shift from previous worldviews, from flight to confrontation to inspiration.

Many people today, however, are living by previous worldviews. Some feel that the church has gone from self-criticism to self-destruction. Science allows for self-criticism, but until recently the Church had avoided self-

criticism. In the Church's admission of wrong in the case of Galileo lies the hope that the Church and the world, religion, and science, will be disposed to learn more from each other.

Theology and Science Now: World Affirming

The Dalai Lama represents the new worldview. Patricia Smith Churchland, neurophilosopher, spoke of her conversation with the Dalai Lama: "I was asked to give a tutorial on the brain to the Dalai Lama. On the issues of science, he wanted information from the people who knew. He was not going to insist that the universe be one way because the Buddhists had thought it was so for 2,000 years. He was willing to change his mind depending on the nature of the evidence" (Moyers, 1990).

It will take a leap of faith for other religious leaders to arrive at such reciprocity, such willingness both to teach and to learn. Thomas Merton made such a leap. He said, "To choose the world is not merely a pious admission that the world is acceptable because it comes from the hand of God. To choose the world is to choose to do the work I am capable of doing, in collaboration with my brother, to make the world better, more free, more just, more livable, more human" (Furlong, 1980). With some irony, this could serve as an excellent job description for a scientist or anyone else involved in genetics.

Pope John XXIII said, "That a marvelous order prevails in the world of living beings and in the forces of nature is the clear lesson to emerge from progressive modern scientific research" (John XXIII, 1963).

Theology and Science: From Conflict to Conversation

In his recent book, *Science and Religion* (1996), John F. Haught, chair of the Theology Department at Georgetown University, identifies four different approaches in the way science and religion can be related to one another: conflict—they are fundamentally irreconcilable; contrast—there is no conflict because they respond to radically different questions; contact—dialogue and interaction between science and religion; and confirmation—religion supports and nourishes the entire scientific enterprise. Haught concludes that "both science and religion ultimately flow out of the same radical eros for truth that lies at the heart of our existence.

So, it is because of that shared origin in this fundamental concern for truth that we may never allow them to go their separate ways."

The word *eros* may be an inspired choice of a word. What scientist would deny the eros element in her work? If there were never an "Aha!" never a "Beautiful!" never a sense of fulfillment, the entire scientific enterprise would go flat. Yet something does attract scientists to the work to be done. Can there be more stimulating work than the genetics revolution? The priest Thomas Berry sees himself as a geo-theologian because of his interest in the science of this planet. Perhaps someday geo-theologians will work side by side with geneticists, sharing what Haught calls this "fundamental concern for truth," which holds such eros for all of us.

Applying Haught's approach, confirmation, in which religion supports and nourishes science, one can say that religion can support and nourish the genetics revolution. However, conversation must precede confirmation. Only after contact, after conversation, can there be support and nourishment. In the Dalai Lama's example, however, this support must be humble, willing to change its 2,000-year-old mind on many things, perhaps willing to see God quite differently, as supportive of the enterprise and supportive of our eagerness to know.

As George Johnson says in his book *Fire in the Mind: Science, Faith and the Search for Order* (1995), "We are inevitably part of the world we are trying to measure, and our observations may be but a single circuit in a great web of flowing bits." Will the genetics revolution turn mere mortals into know-it-alls? This will never happen. The geneticist David Suzuki, concerning himself with what he calls "genethics," says that "we may log the entire three billion letters in the genome, but this will not suddenly give us an understanding of what it means to be human." This last task is never ending.

Robert Francouer: Scientist, Theologian, Early Catalyst

Robert Francouer, scientist, theologian, and early catalyst, made such a leap in 1970 in his groundbreaking book *Utopian Motherhood*. He observed: "We stand on the brink of a major revolution. Genetic engineering, among other advances, will have great psychological, emotional, and religious repercussions. The Creator has somehow shared with us his omnipotence. Having created us in his own image, he now asks us to share with him in the ongoing creation of humanity. Nevertheless, we

are mere neophytes in the task of creation. We lack wisdom and experience and thus often end as bumbling, confused gods" (Francouer, 1970).

Toward a Sense of Ownership

To arrive at a sense of ownership through dialogue, geneticists and believers—and many geneticists are believers—can agree on some ground rules. Richard A. McCormick, S.J., of Notre Dame University, inspired some ground rules in his response to a document from Rome on bioethics (1987):

- (1) Let reason and faith inform each other. Not reason without faith. Not faith without reason. The first is rationalism. The second, our current temptation, is fideism. Vatican II stated that faith directs the mind. It does not anesthetize it. Whether authority comes from science or theology, authority must not replace human experience, human deliberation, human grappling.
- (2) Adopt an open and processive procedural model. Let points of view be welcomed and heard. Scrutiny and response are healthy signs. This process will immeasurably enhance decisions and other consequences. Neither science nor theology can afford to be baroque. No secrecy. Let the world watch and share in all the wrestling and deliberations. Let nothing appear seemingly out of nowhere.
- (3) Accept that the genetics revolution is in constant flux. Everything that we learn together is provisional and open to revision. Ethics too are subject to change. Obligations can be present and real without being exceptionless and unchangeable. On the Church's side, faith, too, can be seen as in constant flux. Consequently, such statements as "wrong for all time" and "contrary to the divine and natural law" and "the Church has always taught" are to be avoided. They are dialogue stoppers.
- (4) All sides must take the competence of others seriously. After all, most moral directives are mixed in nature, or better still, messy. For example, it is one thing to say that human procreation must conform to and promote human dignity. It is quite another to assert that "in vitro" fertilization for otherwise infertile couples violates that dignity. A respectful dialogue practiced with genuine reciprocity could close such gaps. Such a dialogue will call upon the experienced and the competent to speak to the questions at hand.
- (5) Faith communities must take ecumenism seriously. Otherwise, the dialogue will break down over who should speak with authority for all Christians, for the Muslims, for the Jews, for the Buddhists, for the Hindus, etc. As noted, this dialogue is not about authority. It is about the human condition. Vatican II dared to say that no matter who "we" are, we can learn from others.
- (6) Be positive in attitude and tone.
- (7) Be aware of the pluralism of those participating in the dialogue. The concerns of the genetics revolution, along with its ethical applications, are universal concerns. To include the widest possible audience in the dialogue, all arguments, all appeals, and the use of language should make this possible.
- (8) Be acquainted with and draw upon scholarly work. This means using every source available to the participants in the dialogue: contemporary experience, contemporary science, and contemporary theology.
- (9) Avoid ideology. Conformity to past experience, past science, and past theology are seen as the sole or ultimate test of truth. Loyalty and agreement are not identical twins. People disagree with those they love and trust. People grope and grow and change their minds over many things. The genetics revolution presents a challenging task for the human family, tasks of healing, tasks of deepening and broadening our self knowledge, tasks that can be faced squarely without loss of faith.

At least three challenges lie ahead for all who want a sense of ownership of the genetics revolution:

- ◆ to become acquainted with the background and present state of the genetics revolution;
- ◆ to meditate seriously on the many implications such research holds for us personally and for humanity overall; and
- ◆ to develop wisdom out of this knowledge and meditation so that each may actively participate in the genetics revolution from within.

Teachers and educators have a greater challenge than all the others. It is a challenge carefully verbalized by Bill Gates in his book *The Road Ahead* (1995). Gates's biology teacher had his students hack up frogs without explaining why. Bill was bored. Then, in his 20s, he read James D. Watson's *Molecular Biology of the Gene*. He con-

cluded that the understanding of life is a great subject and that biological information is an important part of that understanding. No matter their disciplines, teachers teach a great subject: the understanding of life. Teachers can make the difference.

Conclusion

In his book *A Dwelling Place for Wisdom*, Raimon Panikkar (1993) states his concerns for a world in which science and technology are all-pervasive. He says that wisdom is needed, but that the technocracy of this age has distorted wisdom and that the scientific worldview has displaced wisdom with modern life. He says that under such conditions wisdom comes as a rich, beautiful, educated lady who doles out gifts, accommodates us in a comfortable and hospitable fashion, relays information, and makes us rich. The price of such advantages, he thinks, is the complication of our existence.

Panikkar then plays with the word *wisdom*, and, quite ironically, appears to point a way out of his own dilemma. The Greek word *sophia* and the Latin word *sapientia*, both meaning wisdom, point to experience, skillfulness, and taste. Panikkar reminds us that St. Bonaventure attests that wisdom has an affective, sense-related, taste-related side and an intellectual, cognitive, scientific side. Therefore, wisdom is both *techne* and *epistome*, both action and knowledge, both practice and theory. The observation can now be made that wisdom is an integrated experience that shapes our life.

Consequently, *techne* and *epistome* are friends, for each other and for us. Therefore, the soft (*epistome*)—theology, art, poetry—and the hard (*techne*)—science, technology, the genetics revolution—can talk with each other through human dialogue.

Science and technology are part and parcel of the complex, chaotic, and resilient fabric of society. There is a germ of truth in every dream that points to enhancement. Such dreams should not be discarded just because they are flawed. It was in our ancestors' caves that theology and art and poetry as well as science and technology began. It is our turn.

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4

The Twilight of the Golds: A Paradigm for Ethical Considerations in the Genetics Revolution Discussion

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Abstract: If your parents had known many of your traits beforehand, would you have been born? One family wrestles with what might happen when humankind seizes the ability to edit the human race in Jonathan Tolins' Broadway play *The Twilight of the Golds*. By presenting the play and following it with a directed panel discussion open to students, faculty, and the public, DeKalb College in metropolitan Atlanta created a forum for public interaction.

Relevant disciplines: genetics, ethics, philosophy, psychology

It is painfully obvious that our technology has out-run our humanity.

—Albert Einstein

Much of the information members of the public receive about the genetics revolution and the Human Genome Project reaches them through popular culture. Cursory magazine articles and talk shows may unwittingly produce vague—or even incorrect—impressions about the scientific community and its genetic research. As the gulfs between some academic departments widen, many college students and non-science faculty members may be among the less-than-informed, despite being on those very campuses where such cutting-edge research is taking place. On most campuses, however, there exists a vehicle for encouraging meaningful and accurate dialogue between geneticists and the public: the theater. By presenting Jonathan Tolins' Broadway play, *The Twilight of the Golds*, and following it with a directed panel discussion open to students, faculty, and the public, DeKalb College in metropolitan Atlanta created a forum for public interaction. The college chose as its year-long Lyceum topic, "Science and Human Values"; all speakers and presentations on the campus were to focus on the topic. The Literary Arts Festival, funded by the Lyceum, chose to present a fully staged, free production of *The Twilight of the Golds*; invite its author, Jonathan Tolins, to speak on campus; and offer the public a *Twilight*-related panel discussion with scientists, ethicists, and artists. The result was a lively, provocative, and informative series of events, all of which centered on the very human dilemma generated by Tolins' drama.

A Plot Summary

Few, if any, of the subtleties of *The Twilight of the Golds* can be gleaned from a mere plot summary. The framework of the play is given here, however, to help the reader understand a few of the basic human issues on which the play rests. As with any work of art, this play offers its audience meaningful questions, rather than easy, pat answers.

All but one of the scenes of *Twilight* is set in the near future in the New York City apartment of Rob Stein, a genetics researcher, and his wife, Suzanne Gold Stein, a buyer for Bloomingdale's department store. First to arrive on this, the evening of their anniversary, are Suzanne's parents, Walter and Phyllis Gold; after them, David

Gold, their son and Suzanne's brother, arrives. David, who is gay, designs sets for the Metropolitan Opera. His current project is the Wagner opera *Götterdämmerung* (*The Twilight of the Gods*), a work that discusses what it means truly to love without question. At the close of the first scene, a rather frank and heated discussion takes place between Rob and David. It seems that Oxy Co., Rob's employer, has developed a new test designed to provide genetic information about a fetus during its first trimester. The ethical implications of such a test worry David, who conjures up the specter of genocide and reminds Rob of their mutual Jewish heritage. Rob counters with comments about "knee-jerk liberals," assuring David all will be well if society will "let each family do what's right." All the discussion upsets Suzanne, who surprises her family by blurting out, "I'm pregnant." Naturally enough, there is great rejoicing over this, as the family leaves for an anniversary dinner at a restaurant. In scene 2, Rob states his belief that Suzanne should have the new Oxy test, as it will yield "just information." Suzanne hates tests of any kind and responds less than enthusiastically. In scene 3, a few weeks later, Rob returns from work one evening with the results of the Oxy test. He seems concerned, which causes Suzanne to jump to the conclusion that their child will be deformed or retarded. Rob seeks to quiet her fears: Their child will be a boy of above average intelligence, probably left-handed, with "ten fingers, ten toes." Suzanne's fears are lessened, but she insists that Rob tell her the whole story. Finally, the first act ends with the Rob's revelation that the tests indicate that their son "will probably be like David," gay. Rob, who is "not thrilled" by this information, reminds his wife that no one has ever been in their situation before: "There is no precedent. It's just us."

Act 2 begins with David visiting his parents' home at his mother's request. She informs David that Suzanne might terminate her pregnancy. David then asks his mother what she would have done if she had known the same information when carrying him. Her evasions confirm his worst fears; just then his father returns from a tennis match. Asked the same question, the father answers more directly. David thanks his father for his honesty and leaves. In the following scene, David visits Suzanne and confronts her. She reminds him of how she supported him when he impregnated a girl in high school, when Suzanne helped the two arrange to have an abortion. She demands his support now, stating she doesn't "have the strength" to rear a gay child. Suzanne asks, "What kind of mother would I be if I didn't under-

stand my child?" Her brother answers, "I'd say you'd be pretty typical." David reminds his sister: "Every human being is a tapestry. You pull one thread, one undesirable color, and the art unravels. You end up staring at the walls."

In the final scene, Rob admits Walter and Phyllis to the apartment, informing them that Suzanne is resting after her stay in the hospital. The parents want to know what happened and are told that "there was a perforation" during the late-term abortion and "Suzanne started hemorrhaging." The doctor "had to perform a hysterectomy." A weak Suzanne enters to join the conversation, and the Steins tell the Golds that once Suzanne finally had decided to terminate the pregnancy, it was difficult to find a doctor who would perform such a late-term procedure without knowing why. Because Oxy Co.'s prenatal test is new and not yet patented, no doctor could be told the reason for the abortion of their healthy son.

David Gold asks his lover, Stephen, to call the Steins and make sure Suzanne is all right. After reporting on Suzanne's condition, Rob is told to find a note David has left for the Golds. In it David explains that his family is "creating a new world . . . one of which I will never be a part." He continues: "I know you love me. And I love you all so much. But we are weak people. You don't love me enough to allow me into your family, and I don't love you enough not to notice." *The Twilight of the Gods* ends with a stirring monologue about "what it means to truly love. Without question."

A Paradigm for Ethical Considerations

One of the strengths of Tolins' play is the balancing of points of view in the script. Each character is given a monologue, an *aria*, in which to express his or her opinion, each of which varies widely. The author's characters are well rounded and very human, embodying both positive and negative traits. The playwright never uses the word *gay* in the script. Tolins refers to the unborn child as being "like David," hoping thereby to guide the audience into a realization that the gay gene in the drama is symbolic of any genetic trait society might find undesirable. It would appear short-sighted, therefore, to dismiss *Twilight* merely as for or about gays. In addition, the play's futuristic time frame provides the distance an audience may need for impartial consideration of *Twilight's* themes.

Although *The Twilight of the Gods* provides an excellent human foundation on which to construct a

meaningful ethics discussion, it alone cannot guide audience members unfamiliar with dramatic analysis through such a discussion. Neither can a drama scholar or an ethicist relay the scientific complexities of the genome project to an audience. Hence, the great value of a guided post-*Twilight* panel discussion among members of the humanities, ethics, sociology, and genetic science communities is evident. With multiple viewpoints given a voice, the many facets of the human genome project can be illuminated. Scientific fact rather than rumor and ethical dialogue instead of simplistic finger-pointing will provide audience members with an overview of the complex moral issues raised by genetic research. The point of such a panel is free discussion, not conclusion. Suzanne in Tolins' play, however, serves as a painful reminder of what can happen to those who choose to avoid rather than confront their problems. A well-chosen moderator should not only prevent any one point of view from dominating the panel, but also ensure that the opinions of each member are treated with respect.

Just as a calm, unbiased moderator is needed for such a lively discussion among experts, he or she is needed also to guide an audience question-and-answer period following the panel. Such periods are easily sidetracked by controversial tangential issues. If the purpose of publicly staging *The Twilight of the Gods* and following it with a panel discussion is to put a human face on the genome project and the difficult ethical issues it raises,

then the inclusion of the public in the overall dialogue is arguably the most important aspect of the presentation. Each member of the public must feel free to ask questions and should receive answers couched in laymen's terms. Only in this way can a meaningful genetics and ethics dialogue flourish. If possible, the event should be free of charge. Those who might never consider attending a play or a science and ethics discussion—viewing these as elitist or academic activities—can often be won over by a poster or radio ad's inclusive wording. By announcing that dress is casual, by placing posters in often-overlooked communities, and, most important, by pointedly stating that "all are welcome" a college can generate a diverse audience for its three-part consideration of the genetics revolution.

A presentation of *The Twilight of the Gods*, followed by both a panel discussion and a question-and-answer period, can benefit many departments within the college, forge links between the college and the larger community, and help the public grapple with the factual and moral complexities of the genetics revolution.

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Tolins, J. (1994). *The Twilight of the Gods*. New York: Samuel French.

Copies of the play and rights for production are available from Samuel French, Inc., 45 West 25th Street, New York, 10010.

5

The Third Genie: Genetic Considerations at the Community College Level

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Abstract: The history of our species has been punctuated by the release of three powerful genies. These genies, fire, nuclear energy, and DNA, possess equal capacities for good and evil. The third genie, DNA, is the most dangerous and powerful of the trinity. Laws, philosophical discussions, and ethics are not enough to control the third genie. An informed public is the ultimate watchdog. Because community college educators have the ear of the community, they must seek opportunities to take the information to the public.

Relevant disciplines: ethics, philosophy, genetics

Introduction

The title of this paper is not intended to serve as a clever metaphor. Rather it is intended to draw a parallel to previous “genies” that have been released by humankind. Fire is the first genie, for it clearly was the singular first event that allowed our species to significantly alter and manipulate the environment. Both fire and nuclear energy possess tremendous capacities to enhance or destroy the vast resources of this planet. By design or by accident, each can release its powers.

These are not the only genies. Genies, after all, tend to remain rather personalized. Indeed, each scientific endeavor seems to support its own genies and perhaps an amalgam of ghosts, phantoms, and spirits that manifest themselves in the form of intradisciplinary bias. Whatever one’s discipline, it is not to be denied that humankind’s ability to manipulate fire, nuclear energy, and DNA have had an incredible impact on every aspect of life.

The Three Genies

For the past two million years our ancestors have struggled to harness the power of fire and extract from it, with reasonable safety, its capacity for good while limiting its capacity for destruction. Today we often bear witness to its destructive might when it slips from our watchful eye. Genie number one is out of the bottle.

For the last 50 years, hundreds of the best minds in the world have struggled to harness the power of nuclear energy. Only after its power was unleashed for war did these same minds turn to apply its awesome power for good. Today we can control its energy and use it for constructive purposes, for the good of our planet. We have borne witness to its destructive might and power. Genie number two is out of the bottle.

Just over 40 years ago, a handful of scientists worked, sometimes as an afterthought, to describe the structure and hence the function of DNA. In 1953, James Watson and Francis Crick succeeded. Today we hold in our hands the power of the gene and with it the ability to alter the fabric of life. We have yet to bear witness to its might and its power when it slips from our watchful eye and control. Genie number three is out of the bottle. And it is the most powerful genie of all.

Fire, under control, can warm, cook, provide comfortable aesthetics, bring light to the darkness, or sterilize an inoculation loop. Out of control, fire can destroy

homes, ecosystems, lives, or merely represent a minor adjustment in the course of natural events. Fire predates our species and will likely be here after our extinction. Fire within our control launched the Bronze Age and fueled the Industrial Revolution. It is indeed an awesome genie.

Nuclear energy has existed since the first micro-second in our universe. Like fire, it predates life and all who would seek to control it. Today nuclear energy runs cities, powers great ships, warms homes, and may eventually be used to destroy the microorganisms contaminating our food supplies. How hopeful to announce that this genie is under control. How is it that we forget its devastating potential as seen in Hiroshima and Nagasaki or in the thousands dead, poisoned, and dying in Chernobyl's aftermath? All three genies share a common quality. Each has an equal capacity for good and evil.

Control

Control of fire is generally accomplished at the local level. Communities provide education and protection to citizens designed to minimize damage and loss due to fire while maintaining control over it. Nuclear energy, controlled by a larger community often referred to as the "nuclear club," is global and held together in a tenuous balance of fear and respect. The reach of this community extends over both peaceful and nonpeaceful uses of nuclear energy. Control of genetic research is limited to confusing social patterns, slowly evolving bioethics, and ill-defined legal positions. Advancing technologies far outdistance the ponderous pace of social, ethical, and legal comprehension. The ability of communities, both large and small, to respond to genetic issues and capabilities must be formed and defined using the following guidelines:

- ◆ Members of the academic and research communities must be responsible for reasonable restraint.
- ◆ There must be a thorough understanding of DNA and genetic research. The physical, chemical, and biological properties and capabilities of DNA must be defined and its potential, both good and bad, elucidated. Knowledge generates respect; respect generates constraint.
- ◆ Science must inform and educate the public. An informed public will generate laws that restrain the financial appetites of research.

- ◆ Because the capabilities of genetic research are as exciting as they are unsettling, the research community must honestly and openly address all issues concerning our genies.

While some guidelines governing genetic research exist, the only real constraints on that endeavor are the limits of imagination and money. Once a question is asked, an answer will be forthcoming; each question is a seed that, once planted, will someday germinate. Can we control fire? Can we harness the power of the atom? Can we redesign our own species? Some say "necessity is the mother of invention"; others insist that curiosity is. A million years ago our ancestors sat mesmerized by fire and pondered its potential. Watson and Crick saw in the simple beauty of a molecule the very code of life.

DNA differs from the previous two genies, fire and nuclear energy; it does not deal with energy. This genie deals with power. To control this genie is to control the form and function of life. Power such as this must not be taken for granted. Power, any power, in the wrong hands is dangerous. Power must be respected as well as understood. Neither the gene nor the research presents the danger. The danger is the application of the information obtained. Within the simplicity of the gene lies its complexity and its power. Watson understood this; Crick would learn, also. What beguiled Linus Pauling, evaded Erwin Chargaff, angered Rosalind Franklin, and confused Maurice Wilkins was that while they were searching for complex answers, Watson and Crick were looking for simple beauty and found it.

Neither brilliance nor a Ph.D. is required to manipulate our genie. A clever high school student can transfer antibody resistance from one bacterium to another; think what a renegade scientist could do.

Protection from nuclear terrorism is achieved through enactment of laws or generated by a universal public outcry saying, "Do not use these terrible weapons." Complex treaties, laws, and ethical concerns will do little to regulate DNA. They can, however, serve as a source of information for the public. The public must be taught to separate the goals of basic research from those of applied research, for it is in the application of our knowledge that we generate the power of the gene.

DNA is not just the "blueprint" of life, it is the "blueprint" of the future of life. Every time we alter the DNA in a cell we alter the future of that cell. Biologists

understand that living systems are, after all, chemical systems expressing the sum of the activities of the individual cells constituting the whole.

The Role of Public Opinion

The world learned of the horrors of nuclear war following the release of genie number two over Japan. Politics and international diplomacy aside, the voice of the people, not its politicians, has held nuclear war at bay for 50 years. It was an informed public that refused to allow its leaders to unleash this genie again. One can only ponder: Would nuclear energy have been released over Japan in August of 1945 if the public had known and understood its power in advance?

Throughout history, public opinion has directed scientific investigation as well as limited it. Charles Darwin proposed his theory to a community already sensitized, curious, and anxious to debate concepts dealing with evolution. Uncompromised by MTV and video games, a literate middle class was well read in science and prepared to explore natural selection as the mother of evolution. Had this community not existed, Darwin's theory would have lain fallow, much as Alfred Wegener's plate tectonic theory did a few decades later. Wegener's theory was derailed by social apathy, two world wars, a stock market crash, and an industrial revolution. It took 50 years for the public and scientific community to accept his theory and the evidence he reported.

In 1957, Christian Barnard, a little-known physician in South Africa's Groote Schuur Hospital, transplanted a heart from one man to another. While this advance was reasonably well accepted by the medical community, the public decried Barnard for playing God. That outcry not only scared capable physicians away from further research on the procedure, but also kept funding at a minimum. A handful of pioneering heart surgeons eventually convinced the medical community and the world that this was a procedure worth pursuing. Today the availability of hearts and other organs suitable for grafting is limited only by public apathy.

Apathy is the child of ignorance and fear. And fear is clearly the partner of ignorance. Throughout history we have seen entire populations manipulated by fear and ignorance.

For example, while medical research pressed for treatments for AIDS, concerned educators pumped information. As a result, an informed segment of the public pushed for changes in lifestyle decisions and

forced political action and policy changes. Although these changes have not stopped AIDS, they have helped slow its explosive spread.

This is not a review of history but an attempt to show that the historical precedent is already in place. The public bears the ultimate authority, directing or forbidding what it will or will not tolerate. The public will act, or fail to act, on the basis of information, ignorance, apathy, or fear.

The Role of Community Colleges

The future of genetic research will be determined by the ability of the nation's educators to educate the nation. Universities devote resources to gathering information through research. In community colleges, resources are devoted to delivering information to the public. It is more than a job; it is a philosophy.

To speak credibly, community college science faculties must be as knowledgeable about genetics as their university counterparts. As members of the academic community, we must be able to demonstrate command of the technologies, command of their applications, and command of their capabilities. As members of the sociocultural community, we must be able to convey these capabilities to the public in a clear and understandable manner.

Community colleges must seek opportunities to take the technologies and information to the public. Civic clubs and organizations often provide a fertile venue for communication. Youth organizations and parent-teacher associations likewise offer similar opportunities.

Education and research are conjoined twins, each with a different occupation. They are inextricably joined at the hip. Community college faculty must go to the reservoirs of discovery and talk with those conducting basic and applied research. One can no longer wait for the information to appear in textbooks or learn of it on CNN. Universities must recognize the capabilities of the community college for informing the public. The mission of community colleges is education. We are positioned where larger colleges and universities cannot always go, the point where the community and the academic world unite. Community colleges are the working class of higher education, the academic liaisons of the community. Community colleges are not just the bridge to higher education, we are components of higher education. We are not the voice of the educated elite,

we are the voice of the educated community. We are the voice that must say to DNA researchers: Proceed, but proceed with caution; explore, but explore with reason; learn, but learn with humility. DNA is not another question that we must answer; it is another answer that we must question.

The most frequent student-generated question in the history of higher education addresses the issue of why a specific unit of information must be learned at all: "Why do I have to know this stuff?" If the question deals with Claude Monet or Tennessee Williams, then the answer might be a philosophical one about the loss of the past resulting in a failure to understand the present. In genetics the answer is explicit: Failure to understand the gene is failure to understand its future and therefore risk not being a part of the future. Clearly, genetic research must not be taken lightly or as a matter of scientific curiosity. When we alter a gene by design or by mistake, we become the mutagen, the anomaly, part of the aberrant sequence whose outcome remains unknown and untested.

The impacts of genetic technologies on the insurance industry, right-to-life decisions, and fetal intervention continue to be argued. Genetic research will affect and direct new treatment initiatives involving genetic manipulation. Immunogenetics has been aggressively assaulting cancer, AIDS, dysfunctional genetics, and autoimmune disorders. The Human Genome Project is

within a few years of completion. Soon the genetic sequences of every intron and exon in the collective human genome will be known. The ethical questions raised by these and other capabilities will be too numerous to count. The bottom line is this: As community and educational leaders, our responsibility is not to deliver answers, it is to deliver information and to deliver it in a clear, understandable, and credible manner.

Genetics is no longer confined to the classrooms and laboratories of strange-smelling buildings at the far end of the campus. The third genie touches everyone's future.

Conclusion

It is not the role of the community colleges to sound the alarm. No alarm is needed. The third genie is not evil, just powerful. Our role is to inform, not to frighten. An informed public will be a vigilant and alert public. As the working class of academia, community colleges have a special responsibility to students and to the extended community to ensure that they understand and are able to respond to the changes occurring in the unseen world of DNA. In the greater picture it is the role of all levels of academia to serve as the moderator between the general public and the research lab. We are, after all, educators first. If it is the role of research to reveal the truth, then it is the role of education to reveal the meaning of the truth.

6

Bioethics in the Classroom

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Abstract: This paper describes the goals, strategies, and sample activities for a unit in genetics and bioethics in a nonmajors' biology class. These methods focus on constructivism and the learning cycle. Information is provided concerning resources for teaching genetic counseling and ethics from a constructivist approach.

Relevant discipline: introductory biology

Background

The mapping of the human genome has created a plethora of dilemmas and ethical situations for genetic counselors, families, couples, and individuals desiring information on themselves and their offspring. Students come to us with little knowledge of the progress that has been made in this area of genetics.

To address the issue of bioethics, a unit for students who are not majoring in biology has been developed. Using constructivist and problem-solving pedagogy, students examine ethical issues by working with case studies both independently and in cooperative groups and compare their decisions with those in the literature. These activities enhance students' critical-thinking skills, and they begin to view science as relevant to their lives.

Rationale for Course Development

A new course for nonbiology majors was developed and implemented with the support of a National Science Foundations (NSF) Collaborative Excellence in Teacher Preparation (CETP) grant. The course curriculum is guided by the recommendations that are contained in the Biological Science Curriculum Study (BSCS) publication "Developing Biological Literacy: A Guide to Developing Secondary and Post-Secondary Curricula." The BSCS recommends that the biologically literate person should be able to reason and think critically and make personal and ethical decisions related to biology. In addition, the NSF grant focuses on teaching and learning styles that reflect current research. One goal of this grant is to provide models of science instruction, with the hope that preservice teachers will accept and utilize them in future practice. Instruction includes a learning cycle with three sequential phases: discovery, or exploration; explanation, or invention; and application.

In the discovery phase, students engage in hands-on independent or small-group exploration in a highly structured learning environment. The main goal is to guide students to an awareness of the principal concepts the instructor wants to convey. In the explanation phase, students and instructor share information, experiences, and insights. Students engage in problem solving and analysis in the context of the larger problem presented initially. In the final stage, students apply what they have learned to a novel situation or revisit the original problem posed. One of the main assumptions of the teaching paradigm is that students actively construct meaning

based on their experience, which is embedded in a larger sociocultural milieu.

"Reproduction and Inheritance" is one of seven content areas explored through a unit on bioethics and Mendelian genetics.

Unit Introduction

What are the implications of genetically engineering biological systems and of the influence of industrial growth and biotechnology on humans and the environment? To address this question, students need a basic understanding of DNA, cell division, patterns of inheritance, the factors affecting genes, and genetic manipulation. The following is an outline of the nine areas for the unit leading up to and including genetic counseling and case study activity in bioethics:

1. Amino acids, DNA, ribonucleic acid (RNA), and protein synthesis
2. Cell division, mitosis, and meiosis
3. Genes, chromosomes, and alleles
4. Sources of genetic disorders
5. Risk factors, methods of inheritance, and family pedigrees
6. Screening techniques
7. Genetic counseling protocol
8. Bioethics, ethical principles, and case studies
9. Gene therapy and genetic manipulation

All of the topics were studied in the context of the initial ethical dilemmas explored.

Exploration Phase

Students are given four case studies (see Four Case Studies, page 32) and are asked to respond to these studies by indicating the personal values and ethics that they utilized in making their decisions. Then students are placed in groups of three or four and directed to share their responses. Later they engage in open discussion. Discussion typically becomes intense, and students are reminded to be open-minded and to be critical of ideas and not people. After these open discussions, students brainstorm about the information and knowledge that a genetic counselor would need to evaluate the case.

Explanation Phase

In the explanation phase, students discuss genes and chromosomes, methods of inheritance, sources of disorders, risk factors, genetic counseling protocol, and treatment. Students use Punnet squares and pedigrees to

work on problems associated with the inheritance of traits. A combination of cooperative group work, lecture, and multimedia are used during this time.

To help students understand what information they need, they receive an overview of genetic counseling. In 1975, a committee of American and Canadian physicians published a definition of genetic counseling: "Genetic counseling is a communication process which deals with the human problems associated with the occurrence, or the risk of occurrence, of a genetic disorder in a family" (Ad Hoc Committee on Genetic Counseling, 1975). According to the quarterly report *Gene Pool* (1990), genetic counseling includes the following phases:

- ◆ **Initial phase interview**—family history, pregnancy and birth history, medical history, clinical evaluation of laboratory tests, metabolic screening and biochemical tests, and prenatal diagnostic tests.
- ◆ **Communication phase**—all information gathered is relayed to the counselors.
- ◆ **Coping phase**—accepting and assimilating information obtained.
- ◆ **Decision phase**—counselors provide support, information, and options, including prevention and treatment. The results and reliability of screening, prenatal tests, and gene therapy are discussed.

During instruction and explanation of each phase, the genetic principles and concepts are introduced, and students sharpen their critical-thinking skills by exploring risk factors using family pedigree problems associated with case studies. According to Mertens (1990), a detailed pedigree is still the most useful way for geneticists and counselors to determine patterns of inheritance. Most of the recent advances in screening have actually enhanced this tool. McKusick (1988) provides an excellent summary on the modes of inheritance and associated examples. Several case histories have been adapted for students to develop pedigrees from the *Gene Pool*. In addition, Lewis (1994) provides excellent examples and problems in a workbook. Students use a case history and pedigree that help them in the application phase of the learning cycle (see Example of Pedigree Problems, page 32).

Application Phase

Students discuss situations where they have personally used the ethical principles reported by Fackelmann (1994). These principles include: autonomy, benefi-

cence, justice, nonmaleficence, veracity, and fidelity. The four case studies were initially developed and presented at the Jackson Laboratory in Bar Harbor, Maine, and later *Science News* was asked to print them and have readers respond to them.

Groups of students revisit the case studies and come to consensus on what they would recommend if they were genetic counselors. Groups are required to include a detailed list of all necessary information, tests, and options available for each case. They must also include an overview of how they would educate and inform their clients concerning inheritance, risk factors, and pros and cons of various screening and therapy techniques.

Summary and Conclusion

This unit integrates genetics and health education. It also provides an excellent transition from classic Mendelian genetics traditionally taught in college biology classes to current issues related to the Human Genome Project. One of the goals of the Human Genome Project is to explore the ethical issues that will continue to arise as more information and technology become available. Students reported that the activities described here allowed them to see how genetics related to themselves and to others.

Four Case Studies

Achondroplasia

A couple who both have achondroplasia, an inherited form of dwarfism, desire a child with small stature as well. They tell the genetic counselor they will abort a fetus destined to grow to normal height. Should the center perform the test, knowing the couple's intent? Explain your answer and determine what principles you are using to validate your position.

Cystic Fibrosis

A couple who already have a child with cystic fibrosis (CF) seek genetic counseling. They want to know their risk of having another child with CF. The tests show that the husband is not the biological father of the child. Who should be told what, if any, information?

Colon Cancer

Doctors have just determined that a 30-year-old woman has familial adenomatous polyposis, an inherited disorder that carries an extremely high risk of colon cancer. The mutant gene underlying the disorder can cause a

fatal case at a very early age. The counselor knows the gene may put the woman's children and her siblings at risk. Yet, the woman refuses to tell her family or allow the children to be tested. What should be done?

Fragile X Syndrome

A pregnant woman worries about her family history of fragile X syndrome, an inherited form of mental retardation. She tells the counselor she intends to abort if the fetus is a carrier of the trait and thus likely to be healthy but capable of passing the defective gene to the next generation. Should the test be done, given the patient's stated intent to abort an otherwise healthy fetus? (Fackelmann, 1994, pp. 408–410).

Example of Pedigree Problems

Case history: A couple, John and Mary, come to you for genetic counseling. They are both in their mid-20s, have been married for two years, and are thinking about beginning their family. However, they are uncertain whether it would be wise for them to have children of their own, since John has polyps (growths of the colon) that can become malignant. John's sister, mother, maternal uncle, maternal grandmother, and maternal grandfather have manifested the disease.

1. Draw a pedigree of this family and determine the method of inheritance for this disorder.
2. Based on your answer, what would be the risk that their first child develops polyps of the colon? What would be the risk for their second offspring?
3. As a genetic counselor, suggest what options are available to this couple?

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7

David's Dance: Historical Responses to Genetic Knowledge

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Abstract: Current knowledge and technology in genetics present contemporary researchers with the ability not only to alter individual genes but to cause radical and sometimes detrimental changes in cultures, thereby creating ethical dilemmas that may strain our ability to act ethically. This paper explores the ways such changes have been addressed in the past in order to help readers consider how ethical issues in biotechnology might be dealt with both now and in the future.

Relevant discipline: ethics

The German philosopher Friedrich Nietzsche maintains that scientific knowledge and its applications in the modern age have surpassed humankind's ability to act ethically. Advancements in the field of genetics have certainly produced major ethical problems. However, these problems are nothing new; they have just taken on a different form. A close look at the cultures of humanity throughout the ages reveals that people have always had an awareness of the rudiments of genetic knowledge and its ramifications. Each age has responded to this knowledge in its own way. If George Santayana is right when he says that those who do not study the past are doomed to repeat its mistakes, then modern peoples can better face these new ethical problems brought about by genetic advancements through exploring their own cultural history.

The dominant result of genetic knowledge is the creation of hierarchies throughout all human culture. Second, genetic awareness has manifested itself in both philosophical and actual systems of hierarchies. Finally, what future hierarchy might be created as a result of scientific genetic knowledge? If we understand that we are genetically programmed to create hierarchies, then we will be better able to deal with new ethical dilemmas brought about by human genome research.

According to Desmond Morris, "Everything we do has an inborn, genetic basis and all our activities have something in common with other species. Uniquely, however, we have built on these animal patterns, exaggerating and elaborating them to an amazing degree" (Morris, 1994, p. 6). In the Old Testament story of David's dance, David conquers Jerusalem and moves the ark of the Lord there because he knows that wherever the ark resides, the tribe will be blessed, and as a result, its numbers will increase. While moving the ark of the Lord, David performs a dance that involves great leaping and disrobing. David's dance is an example of a stereotypical courtship display, an aspect of human activity that is the result of a genetic instinct that we, as humans, share with other animals. In this type of dance, the participants gather to display themselves for scrutiny by members of the opposite sex. The aim is to "attract the fittest partner and maximize the chance of getting chosen themselves" (Kluger, 1996, p. 42). Thus, a courtship display is an inborn genetic behavior designed to ensure continuation of the species and passage of fit genes into the next generation.

Examples of genetically programmed courtship displays abound in the animal kingdom. A classic example of courtship display is performed by the three-spined stickleback. Here, the male assumes a brilliant red belly

and performs a darting dance to entice the fecund female into his nest. Another example of elaborate patterned display is that of male prairie chickens, which attract large numbers of females at leks (assembly areas where animals carry on display and courtship behavior). The female prairie chickens nonchalantly forage along the perimeter of the lek until the dominant male has established himself. Then, one by one, these females copulate with him. Cranes offer yet another example of an innately derived dance. The dance of cranes involves a series of vocal calls and stereotypical head, neck, and wing movements. Many other courtship displays are prevalent in the animal world. In each case, the participant animal, without conscious awareness, is utilizing a genetic behavior to ensure the perpetuation of its genes into the next generation.

Viewing David's dance as a genetically programmed stereotypical courtship display is consistent with explaining aspects of human behavior and ultimately human culture as the result of inborn genetic traits. E. O. Wilson boldly states that "the question is no longer whether human social behavior is genetically determined, it is to what extent" (Morris, 1994, p.19). To explain the variety of characteristics among human cultures, one may look into Jungian archetypes. According to Jung, we are born with the collective unconscious of the species, a sort of innate genetic memory. This collective unconscious is a residue of our species' past and, as such, is the cultural evolution of our genetic traits. (Jung believes that the collective unconscious is a kind of genetic memory in which present activity is based on past experiences.) The ideas and images of the collective unconscious are called archetypes. This genetic memory is innate.

That archetypes exist in the animal world can be seen in the following examples. The classic study is that of newly hatched chicks which scurry for cover when a hawk flies overhead. This reaction is so instinctive that when a hawk's silhouette is pulled over caged chicks, the same response occurs. However, when the silhouette is pulled in the opposite direction, causing the cutout to appear as a goose, no response is recorded. At this point in the hatchling's life, it has no learned experience on which to base its reaction. Thus, the behavior is archetypal; it is genetically programmed behavior.

Another archetypal example revolves around the color red. A baby seagull is attracted to the red spot on the parent seagull's beak and pecks at it. This pecking stimulates the parent to regurgitate its food for the chick to eat. In some male birds, strategically placed

red plumage attracts females for mating. A swollen red vulva in some mammals alerts males when females are in estrus. Human females paint their lips red and wear red dresses to be noticed. Red feathers are very important in the headdresses of certain tribes of people. Thus, red coloring seems to be an archetypal method through which animals are signaled, thereby eliciting certain stereotypical responses. As these cases show, when "some very deep chord is struck" (Campbell, 1959, p. 31), certain responses result. These responses to sign stimuli are archetypes.

Programmed courtship displays are archetypes. Just as they exist in cultures of other species, many experts believe they exist in the cultures of *Homo sapiens*. David's dance is an archetype. Through natural selection, those males who performed the best dance habituated the most females and successfully copulated and passed their genes on to the next generation. As a result of natural selection, the most successful courtship display was passed on as a genetic trait. The archetypal view of human behavior argues that David was unaware of his programmed performance. On the surface, he was engaged in a religious ritual, while in reality he was acting on a genetically transmitted archetype.

Unlike other animals, humans have self-awareness. Therefore, we can consciously think about what we are doing. There is a mild pretense that hides the intent of the cultural behavior taking place. This hidden agenda is, in fact, an archetypal pattern is shared by all cultures, both human and animal; the shape it takes is based on its cultural environment. To paraphrase Joseph Campbell, a single god wears many masks.

For example, all social group cultures have archetypal incest taboos. While group living offers the advantages of protection from predators, food security, and reproductive success, it harbors the possibility of inbreeding, which may give rise to deleterious genetic consequences. Social groups limit this hazard by excluding members of one sex from the group when they reach sexual maturity. In birds, the females usually leave the group and take up residence in other groups. In many mammals, the males leave the birth group (Greir and Burk, 1992). Elephants, with their matriarchal hierarchy, serve as an example of males forced from the birth group. Alternatively, in chimpanzee and human groups, related males form alliances and females are forced from the birth group. Throughout human history, the exchange of sisters and daughters between social groups not only decreased the

chances of inbreeding but also encouraged powerful alliances between groups or tribes.

The human incest taboo is most notably recognized in the Greek tragedy based on the mythical story of Oedipus Rex. Here, Oedipus unknowingly kills his father and marries his mother. Generally, mother-son intercourse is considered among the most offensive of the incest taboos. When Oedipus discovers his horrific transgression, he punishes himself by self-mutilation to atone for his sins. This myth warns against incest and, as such a warning, it is one culture's response to the genetic archetype that inbreeding decreases genetic fitness.

Human cultures throughout the world have various courtship displays. In each case, the cultural environment dictates the outward exhibition. In some cultures, for example, an elaborate code of dress might be involved. The outward show of the archetype might vary in females from off-the-shoulder styles that expose bare shoulders to short skirts that reveal the knee. In any case, the culture determines what is sexually attractive. A code of behavior might be involved as well (Morris, 1992). Courtship rituals in regard to behavior might consist of anything from batting eyes to buying drinks (Kluger, 1996). Again, cultural environment dictates the representative form of the archetype. In the dance of David, we see the courtship display take the form of a stylized religious ritual.

According to this approach and theory, human culture is a by-product of genes. First, human activity has a genetic basis. Second, this activity is the result of genetically transmitted archetypal patterns. Finally, these archetypes reveal themselves according to the nature of the culture that produces them.

It would follow that the dominant cultural consequence of genetic activity is the establishment of hierarchies among all cultures. By definition, a hierarchy is a system of arrangement according to rank. An example from the animal kingdom is the dominance hierarchy. In wolf packs, for example, there are an alpha male and an alpha female. Only this pair mate and produce offspring. The subordinates protect, hunt, and help to care for the alphas' cubs to ensure their survival.

Human cultures, being more complex, have a greater number and variety of hierarchies. For example, in government a ruler is historically at the top. This ruler has subordinate leaders that may vary from princes or senators to a military stratum. Ultimately, the masses are at the bottom. Hierarchies can be seen in

other examples of human culture as well: religious, military, economic, and social.

There is a connection between human and animal hierarchies. Even though we may not call religious, military, economic, or social hierarchies dominance hierarchies, the rank and order are established among the members of the group. The desire to order society appears to be innate. In support of this instinctive trait, one need only consider the vastness of the hierarchies that exist across human culture and the different forms that these strata take.

Past cultures have been governed by the rules of heredity. For example, in the *Republic*, Plato puts forth the idea that it is possible to have a harmonious society that serves the needs of all citizens. To achieve this end, he proposes a societal structure that is often referred to as the theory of metals. The contents of this theory, which include arranged marriages selected according to phenotypic traits, may be considered genetically based.

To summarize Plato's theory, the idealized society contains certain classes to which he gives the names of various metals. They are gold, silver, and base metals. The members of the gold class are qualified to act as rulers or philosopher kings. They are chosen on the basis of natural levels of intelligence, and once chosen, they are given the best education and are put to use as guardians of the state (Lavine, 1984, p. 60). The silver class contains the auxiliaries. These are the professionals. The final class consists of the base metals. These are the producers.

This idea is hierarchical in nature. It is an attempt to arrange the classes in order to best achieve an idealized society. In this hierarchy, there is a division of labor whereby people are placed according to their innate abilities. To accomplish the goal, the rulers used selective breeding not only to produce the members of classes but also to achieve the best possible offspring within these classes and to ensure the continuation of the traits that the classes embodied. Plato uses outward expressions of genes to create a hierarchy that has as its goal, a structured, efficient society.

There have been other examples of philosophical hierarchies developed in human cultures as well. Nietzsche, for example, proposes the idea of the "superman." He suggests that there are some who are "better" than the rest and can "become gods" (Lavine, 1984, p. 325). In the democratic system of John Locke, a hierarchy can be seen as well. However, in his case, the arrangement is in the reverse of the historical precedent, whereby a king rules by divine right. In Locke's theory,

the common man rules and has the right to overthrow the government (Van Doren, 1991). In other words, hierarchies vary according to philosophical viewpoint.

As these examples illustrate, human culture can create philosophical systems that have hierarchies as their bases. The order of these hierarchies can vary. In some, there is a "fit" leader such as Plato's philosopher king. In others, as with Locke's notion of democracy, the leader is there only as long as he responds to the collective will of the people. One might question whether these philosophical hierarchies would have been created had humans not had an intuitive knowledge of human genetic traits.

Philosophical approaches are just that—they are worldviews. However, they can also become reality. One example of an actual hierarchy being put into place on a grand scale is the 17th- and 18th-century notion of the Great Chain of Being. This is the idea that "the whole universe . . . consists of an ordered series of beings, from the lowest, simplest, and tiniest at the bottom to the highest and most complex at the top" (Boorstin, 1983, p. 457). Within the total world hierarchy, God is at the top, man is in the middle, and Satan is at the bottom. There are hierarchical divisions inside this overall scheme as well. For example, this system can be seen in the societal structures of man. One may see this scheme in the church, where the laity is at the bottom and the pope is at the top. Tillyard asserts that there is a ranking structure in the animal kingdom also. The dolphin is the highest among fishes, the eagle among the birds, and the lion among the beasts (Tillyard, 1942). In other words, if this Great Chain of Being pervades all aspects of life, humanity has based all of society around a highly detailed classification system based on preconceived notions of quality.

Many hierarchical systems have been established in world cultures. Within the Hindu caste system, for example, the Brahmans are at the top and the Pariahs are at the bottom. Movement between casts is strictly controlled. To marry outside the caste is a sin, whereby one is damned to hell and forced to embrace red-hot human forms (Wilson, 1978). The idea that some are inferior to others and will never escape their origins pervades the system.

As these examples show, philosophical ideas can become the culture. Plato's theory of metals proclaims an ordered, structured basis for controlled breeding. In the culture of the Great Chain of Being, one is born a link in the chain and must remain there, for any attempt to rearrange the links is a sin. Plato's philosophical structure became reality. If a philosophy has

been made reality before, then it can be done again.

Currently, genetic knowledge has taken the course of a scientifically based attempt, known as the Human Genome Project, to map the entire human genetic code. This project holds the very real possibility for both use and abuse. It might ultimately be used to defeat possibly fatal inherited disorders such as cystic fibrosis and hemophilia. The knowledge gained from gene mapping and sequencing might also combat genetically based conditions such as dwarfism and color blindness. Eventually, it may provide information that will better limit the damaging mental retardation in people with the inherited abnormality of phenylketonuria. On the other hand, it may lead to such morally debatable practices as gender selection in human reproduction and in eugenically engineering traits such as strength and intelligence. Truly, this is a project that holds a vast array of possibilities and dilemmas.

In earlier portions of this analysis, we have discussed the effects of genetic awareness on human culture. In the past, cultural assimilation of awareness of genetics was slow and knowledge had adequate time to be fully incorporated into the cultural framework. For example, within the Hebrew religious structure, sacrifice of abnormal children was established to be wrong beginning with Abraham and Isaac. Keeping an abnormal trait in the gene pool was damaging to the species. Killing an infant with such traits came to be perceived as morally wrong. Ultimately, an action that would keep the culture genetically fit (infanticide) was prevented by making that action sin. However, time was needed to incorporate this genetic idea into the culture.

Because of the swift pace of the Human Genome Project, there is little or no time for cultural assimilation. It is projected that the human genome will be mapped by the year 2003, and the project is already ahead of schedule. One can only imagine the amount of information that we will gain from this endeavor and its impact on society and culture. Technology has outpaced the culture that produces it. This is the cultural equivalent of the inability of the human organism to withstand such technological advances as the G-forces produced when flying modern fighter jets. Pilots black out under such forces because human physiology is no match for this technology. Herein lies the dilemma of the Human Genome Project. The findings can be used for good or ill. How will we know what is good or ill if our culture does not have time to assimilate this information as it did in the past?

If all human behavior has a genetic basis and if genetic awareness manifests itself in the development

of hierarchies, the dilemma involved here revolves around how the hierarchy based on the Human Genome Project will be created. How and by whom will decisions be made? Will they be based on eugenics? Will future cultures discriminate on the basis of genes? Already we have instances of job, social, and marketplace discrimination against people who have undergone genetic testing. There will be consequences of such a genetic hierarchy. No matter what the basis, the hierarchy will be established.

New ethical dilemmas will arise with modern scientific advancements in the Human Genome Project. Our ability to react ethically with present and future knowledge will depend on our knowledge of the past. We have had a genetic awareness throughout our history that we assimilated slowly into our cultures. Leo Strauss maintains, "All the hopes that we entertain in the midst of the confusions and dangers of the present are positively or negatively based on the experiences of the past" (Morris, 1994, p. 19). Today, scientific findings will come far more quickly, so we must build on our knowledge of the past to predict and prepare for the future. What will we do?

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PART II

Biology, Nursing, and Allied Health Courses

8

Educating the Educators: The Genetics Revolution in the Community College Setting

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Editor's note: This paper serves as a brief introduction to the history of genetics and the Human Genome Project. A discussion of the molecular structure of genetic material is provided for those unfamiliar with the language and theory of molecular genetics. The goals of the HGP are outlined along with major issues related to public policy and education.

Abstract: Community college instructional personnel must be prepared to inform their students and the community about the explosion of genetic information that directly influences their lives. In addition, they must provide a background in genetic science to students who wish to pursue a baccalaureate degree in related areas. This paper provides information on the foundation of modern genetics, the significance of the Human Genome Project, and the problems that arise with new genetic discoveries.

Relevant disciplines: biology, psychology, law

Introduction

A major issue currently changing the perspectives of those who deal with education, business, economics, ethics, medicine, law, and law enforcement is that of genetics and recombinant DNA technology. The culmination of this explosion of knowledge is embodied in the highly visible yet often misunderstood program, the Human Genome Project, or HGP (Cooper, 1994; National Research Council, 1988). The ultimate objectives of the project are to sequence the three billion human DNA base pairs and to identify all human genes by 2005. The project had its beginnings before a 1984 meeting in Utah when the federal government's Office of Technology Assessment acknowledged the value of a human genome reference sequence in view of the increasing demand and growing role of recombinant DNA technology.

In 1985, a group of scientists interested in sequencing the human genome met at the University of California, Santa Cruz. Several other workshops followed, and in fiscal year 1988, Congress officially launched the U.S. Human Genome Project. Funds were appropriated to the Department of Energy (DOE) and National Institutes of Health (NIH), and a memorandum of understanding was signed by these agencies to safeguard against future conflicts. In October 1990, the project formally began. An understanding of the goals, objectives, and methodology of this program as well as of its ethical, legal, and social implications requires a knowledge of basic genetics concepts.

Genetics: Past and Present

The study of inheritance, genetics, dates to ancient civilization. However, genetics as an empirical science can be traced to the development of the microscope, which paved the way for the visualization of the cell and its nucleus. Progress in microscopy led to the development of cell theory, the backbone of biology, which states that all cells come from preexisting cells. With the publication in 1859 of Charles Darwin's *On the Origin of Species by Means of Natural Selection*, the stage was set for a scientific revolution that continues to this day (Stubbe, 1972).

Pioneering Discoveries

In 1866, the work of Gregor Mendel, outlining the rules of genetic inheritance, was published, but it was largely ignored by the scientific community. Meanwhile, discoveries in cytogenetics (cellular genetics) were taking center

stage. Improvement in microscopy and staining techniques revealed the behavior of chromosomes. It was suggested, rightly, that chromosomes are the physical link that maintains cellular continuity from generation to generation. During this period the fusion of the sperm and egg nuclei during fertilization also was described. By the 1890s, meiosis, the division process that reduces the genetic material in half to produce the gametes, or sex cells (sperm and egg), was clearly elucidated. But even with these cytological advances, the biologists of the period struggled in vain to answer the question of how character traits were passed from parents to offspring.

Modern Genetics

The progress made in cytogenetics and chromosome behavior studies ushered in the era of modern genetics. In 1900, three biologists, Carl Correns, Hugo de Vries, and Erich von Tschermak, working independently of one another, rediscovered Mendel's landmark 1866 work on the rules of inheritance (Stubbe, 1972). For the next four decades, biologists worked incessantly, determined to find answers to the question that had baffled them for years: How are character traits inherited?

Mendelian Inheritance

Gregor Mendel kept detailed records of his breeding experiments on garden peas, and he relied on exact mathematical relationships to describe his observations. From these breeding experiments emerged two genetic principles that became the foundation of modern genetics. The first Mendelian principle is the law of segregation. Mendel assumed that each plant carried a pair of determinants for every character trait. These determinants, today called genes, exist in at least two alternative forms called alleles. A gamete receives one determinant (one allele) for each trait. The union of two gametes at fertilization restores the original complement of determinants (the allelic pair). This in essence is how Mendel described the mechanism of inheritance of one character trait.

The pattern of inheritance of two different character traits is explained by the second Mendelian principle, the law of independent assortment. In the present context, it states that the alleles of one gene segregate independently of the alleles of another gene. For example, the gene for the character "height" has two alleles, or alternative expressions, "tall" and "short." The gene for the character "color" has two alleles, "green" and "yellow." At gamete formation, the alleles "tall" and "short" are distributed to two different gametes. The alleles "green" and "yellow"

are distributed likewise to two different gametes. The allele "tall" can be in the same gamete as the "green" or the "yellow" and so can the allele "short." At fertilization, the original complement of alleles is once again restored. In this example, a plant that is tall and bears yellow seeds, when bred (crossed) with one that is short and bears green seeds, will produce some offspring that have different character combinations from the parents. Some offspring will be tall and green, others short and yellow, and still others will be identical to the parental types. Because each allele segregates independently, new character combinations emerge in succeeding generations. Mendel's habit of meticulous record keeping of offspring count and breeding ratios was critical in proving these principles.

Chromosomal Inheritance

When a cell is not dividing, granules of chromatin materials are dispersed throughout the nucleus. When the cell divides, this nucleoprotein material condenses and become visible as chromosomes. Each chromosome has a centromere, a visibly constricted region for spindle fiber attachment. For any given chromosome, the centromere position is fixed; this is a convenient marker for dividing the chromosome into regions called arms. Anatomically, a typical chromosome has a long arm and a short arm, with the centromere in between. When treated with certain dyes, chromosomes exhibit characteristic bands that are fixed in position. Chromosome banding is the primary tool of cytogenetics. It is used to identify specific chromosomes when constructing an idiogram (picture or diagram of a chromosome complement arranged in descending order). It is also a tool in determining any chromosomal aberrations. A missing chromosome region can be identified by a missing band, and a transposed or added region is shown by an extra band. The physical relationships of genes that lie on the same chromosome (linkage group) can be established by the analytical technique of chromosome mapping. Through controlled breeding experiments, the locus (location) of the genes and the distances among the genes in a linkage group can be established. Linkage maps are essential in establishing the location of specific genes within a chromosome.

Molecular Genetics

The period of molecular genetics started in 1944 with the definitive demonstration of DNA as the material of inheritance. In 1953, James Watson and Francis Crick described the molecular structure of DNA. The next two

decades saw an exponential growth in the development of DNA-based technology. The discovery of restriction endonucleases, enzymes that cut DNA strands at specific sites, provided the molecular scissors that enabled scientists to manipulate genetic material, to “cut” DNA segments from one source and “paste” them in another, producing a DNA molecule that is partly one organism and partly another. The term *species* had taken on a new meaning. The excitement of the scientific community over this new frontier was not eagerly shared by the rest of the population, partly because of the inability of the scientific community to communicate the information in a manner understandable to nonscientists. A proliferation of science fiction entertainment fueled the growing fear and intimidation that was building up in some segments of the population. Meanwhile, academic curricula in primary and secondary schools began to incorporate some of the new information generated by molecular genetics research. Students entering postsecondary schools began to hear more and more about DNA and its power as the driving force behind evolution. With these scientific discoveries, students and teachers alike had to learn new definitions, new scientific terminology, and new laboratory techniques.

Deoxyribonucleic Acid (DNA)

For a molecule to qualify as genetic material, it must have unique structural properties. It must be able to carry the information that controls the synthesis of enzymes and other proteins in the cell and to self-replicate with a high degree of fidelity and a low level of mutation, and it must be contained in the chromosome. DNA possesses all these properties and more. It consists of nucleotide subunits linked together to form a strand. Each nucleotide consists of a five-carbon sugar, a phosphate group, and one of the four nitrogen-containing bases: adenine (A), thymine (T), cytosine (C), and guanine (G). The alternating sugar and phosphate molecules form the backbone, while the nitrogen-containing bases stick out on the side of each strand. A molecule of DNA consists of two strands wound together in a helical fashion. The molecular attractions between two nitrogen-containing bases on opposite strands hold and maintain the helical shape of the DNA molecule. These molecular attractions, also called base pairing, follow strict pairing rules: A will pair only with T, and G will pair only with C. The molecular bonds between the alternating sugar and phosphate groups are strong and are not easily broken, whereas the molecular attractions between the nitrogen-

containing base pairs are rather weak. The implication is that the two strands can be separated easily, while a strand by itself is more difficult to break.

DNA Replication

A genetic molecule must be able to make copies of itself with very few mistakes, preferably none at all, to ensure that copies passed on to the next generation are identical to the original. DNA replication occurs when certain enzymes separate the two strands of the DNA double helix by breaking the molecular attraction between nitrogen-containing base pairs, exposing the individual nitrogen-containing bases that stick out on the sides of both strands. Free nucleotides in the surrounding area move in and pair with the nucleotide in each strand. Again, the strict pairing rules apply. As each free nucleotide pairs with the bases in the DNA template strands, enzymatic action chemically links their phosphate and sugar components, forming two new DNA strands with a base sequence complementary to the template strands. Another set of enzymes restores the helical shape of the new molecule; only this time, the DNA consists of the old template strand and the newly synthesized complementary strand.

The original DNA strand has now given rise to two identical DNA molecules, each one consisting of an old and a new strand. The DNA molecules are distributed to the two new daughter cells as cell division proceeds. High fidelity in replication is achieved because the enzymes that join the strings of new nucleotides to form the complementary strand also act as “proofreaders,” preventing the wrong nucleotide from pairing with the base in the template strand. On rare occasions, however, errors in enzymatic proofreading may occur and a wrong nucleotide becomes a part of the new DNA. This change in the sequence of nitrogen-containing base pairs is called a mutation. The mutation will be passed on to the next generation as the DNA replicates once again. Ordinarily, mutations are looked upon as undesirable, and in some cases they are. Inherited genetic diseases are mutations of genomic DNA (genes) that are passed on by parents to offspring. Most mutations, however, are the facilitators of evolution, allowing the organism to adapt to the changing environment, increasing its chances of survival.

Ribonucleic Acid (RNA)

Like DNA, RNA also is a long molecule that consists of nucleotide subunits. But whereas DNA is a two-stranded molecule, RNA is a single strand of unbranched

nucleotide chain. The nucleotide subunits of RNA consist of a five-carbon sugar that has one more oxygen atom than that of DNA. The nitrogen-containing base thymine in DNA is replaced by uracil in RNA. And whereas there is only one type of DNA, there are three different types of RNA molecules, each one having a specific function.

Genes

Genes are segments of DNA that carry the blueprint for the synthesis of enzymes and other proteins. The blueprint refers to the sequence of nucleotides in the DNA strand. This blueprint is copied with fidelity when the DNA replicates, hence every generation receives the exact copy, unless mutation occurs. There are an estimated 3 billion DNA base pairs in the human genome (all genetic material in the chromosomes). An estimated 50,000 to 100,000 genes, or "coding sequences," are embedded in this pile of DNA. The rest of the genome, approximately 95 percent, contains noncoding sequences and is sometimes called "junk" DNA. When DNA replicates, both genomic and junk DNA are replicated. The chromosomes carry both coding and noncoding DNA into the next generation.

Protein Synthesis

The flow of genetic information from the gene to its ultimate product (protein) is summarized in the central dogma originally proposed by Francis Crick (1970): DNA → *transcription* → RNA → *translation* → Protein. (The genetic code is transferred from DNA to RNA through a process called transcription. The coded RNA sequences amino acids in protein by transcription.) There are differences between the prokaryotic (cells without true nuclei, like bacteria) and eukaryotic (cells with true nuclei, like animal cells) systems, but for the most part the mechanisms of protein synthesis are similar. In eukaryotes, the DNA is located inside the nucleus, while protein synthesis occurs in the cytoplasm. DNA transcription begins when, in response to certain internal or external signals, enzymes attach to a "promoter" segment in the DNA located at the beginning of a gene.

The DNA double helix unwinds, exposing the nitrogen-containing bases. As the linear unwinding process continues, free nucleotides move in and pair with the template nucleotide following the strict base-pairing rule. The growing strand substitutes the T with the U (uracil) nucleotide. Unlike DNA replication, only one strand of the DNA is transcribed, or copied. The

unwinding and transcribing process continues until the enzyme comes to the "terminator" segment at the end of the gene. At this time, the newly synthesized molecule, called messenger RNA (mRNA) detaches from the template, and the DNA once again returns to its original double-stranded form. The nucleotide sequence of the newly synthesized mRNA is complementary to the base sequence of the transcribed DNA strand, the gene.

The gene itself is an array of nucleotide segments, some of which are not essential in protein synthesis. The sequences essential for protein synthesis are called exons (expressed sequences), while intervening, nonexpressed sequences are called introns (intervening sequences). The mRNA is enzymatically modified by removing the introns before it is released into the cytoplasm. The mRNA carries the code, the specific linear array of nucleotide sequences of the gene, from the nucleus to the cytoplasm. Translation begins as the ribosomes, with their ribosomal RNA (rRNA) and protein, read the message carried by the mRNA, three base sequences at a time. Each three-base sequence is called a codon, which specifies one amino acid.

There are 20 naturally occurring amino acids and four nucleotides in the DNA. The genetic code, consisting of 64 nucleotide triplets, contains some overlaps, meaning that some amino acids are coded by more than one triplet. Amino acids are the building blocks of protein, and free amino acids are found in the cytoplasm. Transfer RNA (tRNA) picks up the free amino acid and carries it to the ribosomes that are reading the code in the mRNA. As the ribosomes read the codon linearly, the specified amino acids are added onto the growing chain of polypeptide. Translation ends when the ribosomes arrive at the stop codon, triplets that specify the termination of the process. The ribosomes detach from the mRNA, and the protein or polypeptide is enzymatically processed into its final, functional form.

DNA Technology

Genetic Engineering

The technology made possible by the discovery of restriction endonucleases enabled scientists to make "designer molecules" by cutting segments of DNA, usually a useful gene, from one organism and inserting it into another. The host organism does not recognize the DNA as foreign because all DNAs are the same: nucleotide segments of A's, T's, C's, and G's. When the host cell divides, it replicates its genome, including the inserted piece of

DNA. The ultimate aim of this procedure is to coach the host organism to transcribe and translate the inserted segment and make the protein specified by its code. Among the early successes of this technology is synthetic insulin produced by bacteria in the laboratory. In agriculture, genetic engineering technology is used to improve the yield and postharvest shelf life of crops and increase the protein content of meat and milk in livestock. In medical practice, gene therapy is gaining ground. The idea is to insert a copy of the correct gene taken from healthy donors, into the cells of patients who have a mutation, in the hope that the cell will use the correct genes and make the protein that is missing because of the mutation.

Genetic Fingerprinting

The technology of genetic fingerprinting was developed by Alec Jeffries and found its first application in solving two murder cases in England (Kirby, 1990; Hagelberg, et al., 1991). Currently, this technology is used to establish paternity in cases of parental disputes and guilt or innocence in criminal investigations. Human DNA contains some long nucleotide sequences that are similar and other sequences that are highly variable. When treated with restriction endonuclease, the cutting sites for different DNA samples also will differ, hence the number of fragments as well as the size of each fragment will be unique for each individual.

When the DNA sample is small, a technique called polymerase chain reaction (PCR) is used to make millions of copies of the sample, providing enough material for analysis (Mullis, et al., 1994). Initially, the sample is digested with restriction enzyme. The resulting DNA digests, or fragments, known as RFLPs (restriction fragment length polymorphisms) are separated into bands by agarose gel electrophoresis (Watkins, 1988). Large fragments will move slowly from the origin, while the smaller ones will move faster. The result is a band of DNA fragments of varying sizes. The DNA band pattern is transferred to a nylon membrane and a radioactive DNA probe is introduced. The DNA probe binds to specific DNA sequences on the membrane. Unbound probe is washed away, leaving behind a characteristic band pattern. The radioactive DNA pattern is transferred to an X-ray film by direct exposure. When the film is developed, the visible pattern is the DNA fingerprint.

The fingerprint of the suspected individual is compared with the fingerprint of the sample from a crime scene and band matches are made. In paternity cases, the DNA fingerprints of the mother, the child, and the sus-

pected father are compared. Bands present in the child that are not present in the mother are derived from the father. This technology is gaining ground and is becoming accepted as an invaluable and effective tool in the administration of justice.

The Human Genome Project

When Darwin was studying finches and Mendel was breeding peas, they made keen observations and asked relevant questions. They had to explain their findings at the population and organismic level, for that was all they knew. Today, almost all biological events can be approached at the molecular level with sophisticated technologies. The project that aims to dissect humans at the molecular level, the Human Genome Project, is in place and is succeeding beyond expectations.

Funding

Funding for the project was initially set at \$200 million per year for 15 years and adjusted for inflation after 1990. By 1995, most of the initial goals had been met or exceeded, with some ahead of schedule and all under budget.

Scope

The Human Genome Project is international in scope and dimension. Recognizing the needs for coordination of research and information sharing and for providing insights on the project results, the Human Genome Organization (HUGO) was formed by scientists from 17 countries. Each country's activities differ, dictated primarily by particular concerns, manpower capabilities, and funding abilities. The United States and Japan are concentrating on mapping and sequencing, while the United Kingdom, Germany, and Italy are directing their efforts and resources at updating and improving databases and managing information systems. Denmark is devoting more funds toward technology development to fight genetic diseases. And in an effort to get the participation of developing countries, the United Nations Educational, Scientific, and Cultural Organization (UNESCO) has been exploring a role as a facilitator of international dialogues and cooperation.

Goals

The initial five-year goals of the project were published in 1993 (Collins & Galas, 1993) and have been periodically updated to reflect the progress being made. The following reflects the project's goals.

Genetic mapping. The original goal of completing the map by 1995 was accomplished one year ahead of schedule, and the goal calls for continued improvement in genetic mapping technologies, effective genotyping methods, and development of new genetic markers.

Physical mapping. Progress is being made on the completion of an STS (sequence tagged sites)-based map of the human genome with markers spaced every 100 kilobases on average.

DNA sequencing. Significant progress is being made toward developing the capability for large-scale DNA sequencing.

Gene identification. The speed with which genes are discovered has increased tremendously within the last two years. It is the goal of the project to identify all human genes, including disease genes and other functional elements of the genomic DNA.

Technology development. The goal is to encourage and support development of technologies that will enhance the progress of the Human Genome Project.

Model organisms. Common research organisms (*E. coli*, *C. elegans*, *S. cerevisiae*, *D. melanogaster*, and the mouse) serve as cost-effective testing grounds for large-scale DNA sequencing for use in human genomic studies.

Informatics. Progress is being made in the development of computer-based systems that will automate, distribute, and manage experimental data and create new databases as the needs arise.

Ethical, legal, and social implications (ELSI). To identify and address issues related to the procedures and results of the project and to suggest options, a program on research and education has been funded and the National Institutes of Health, Department of Energy Joint Working Group, was formed. Guidelines on the conduct of genetic research, responsible clinical integration of new genetic technologies, privacy and fair use of genetic data, and professional and public education have been set and are constantly revised and updated.

Training. The interdisciplinary training of scientists is being encouraged. The National Center for Human Genome Research financially supports minority and disabled students pursuing careers in the sciences.

Technology transfer. The transfer of information from within as well as outside of the genome research centers is encouraged. Technology transfer has been ongoing through interactive collaboration between genome researchers and the private sector. Increased cooperation

with industry and between agencies is recommended.

Outreach. The goal of the project is to make the findings generally available and accessible. To date, Web sites on the Internet have provided a wealth of information for almost everyone, and they facilitate an exchange of ideas and opinions.

Accomplishments

One purpose of the Human Genome Project is to provide an infrastructure in the form of technology and material resources that will enhance the capabilities of biological researchers. The genetic map played a major role in the identification of 13 disease genes in fiscal year 1995 alone, including BRCA1, the hereditary breast cancer gene (Miki, et al., 1994). Other disease genes identified include Menkes' syndrome, X-linked immune disorder ammaglobulinemia, Huntington's disease, myotonic dystrophy, fragile X syndrome, and neurofibromatosis types 1 and 2. The discovery of disease genes has prompted the development of genetic testing protocols that will reveal an individual's predisposition to a disease. And while there are still no known cures for most of these genetic diseases, the fact that they have been identified at the molecular level provides the first logical step in eventually developing and finding the cure.

Ethical, Legal, and Social Implications

The major concerns surrounding the Human Genome Project are not so much the sequencing of the genome as they are how the information will be used, who should have access to it, and how this information will affect the individual, the family, and society. Issues having the greatest impact on society are those of privacy, fairness, clinical application, and professional and public education.

Privacy. Among the areas of focus for genetic testing are prenatal diagnosis, newborn screening, carrier screening, forensic testing, and susceptibility screening. There is a growing fear that genetic screenings will become routine procedures that will expose one's genetic susceptibilities, even before birth, to anyone who has a vested interest.

Fairness. If everyone's genetic profile is available and some enterprising individuals develop a technology or commercially profitable enterprise based on someone's genetic profile, the question of who should benefit financially becomes a legal issue. For example, a genetically engineered drug with potential for curing a genetically inherited disorder could be developed using the genetic profiles of individuals who have the disease.

Clinical application. More and more physicians and health care providers are faced with the dilemma of informing patients about medical conditions based on genetic testing. Without adequate education and counseling, the psychological impact on the patient could be overwhelming.

Professional and public education. Professional schools, especially those involved in training medical and health care practitioners, are fast becoming converts to the idea of including genetics education in their curricula. Programs to assist federal and state judges in understanding genetic evidence, curriculum modules for primary and secondary schools, teacher training workshops and short courses on genome science are all available.

Nonbiologist Educators and the Genetics Revolution

Information based on genetics and DNA-based technologies has permeated every aspect of the academic world. Psychology and sociology textbooks are incorporating information on the legal and sociocultural implications of the Human Genome Project. Criminology classes are devoting more time to the discussion of DNA fingerprinting. Humanities classes are using issues in human genetics for expository writing and research paper exercises. And business and economics classes are talking about the impact of new drugs developed through genomic technologies. Educators must be prepared to discuss and evaluate the issues of the genetics revolution and the Human Genome Project.

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9

Field of Dreams— “Build It and They Will Come”: Building a Program in Genetics at the Community College

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Abstract: Delta College has implemented several genetics courses designed to increase the awareness of students and the public about new genetic technology and related ethical implications and to prepare students interested in careers in biotechnology to transfer to a four-year institution in the state. Delta provides educational opportunities in genetics through conferences, workshops, and presentations to local groups. Resources related to genetics education are listed.

Relevant discipline: genetics, biotechnology

Introduction

Genes are at the heart of the existence of life, and yet only in recent years have molecular biologists begun to unravel the mystery of their action. Although inheritance patterns have been of interest for centuries, major strides in understanding human inheritance at the molecular level did not occur until the discovery of the structure of DNA in 1953. Consequently, the average person knows little about the nature and function of genes. Growing interest in human genetics on the part of the media and the general public presents educators with an opportunity and a challenge to bridge the gap between the professional and the layperson.

Modern Human Genetics

In 1988, geneticists around the world, working under the auspices of the Human Genome Organization (HUGO), embarked on the Human Genome Project. Molecular biologists are beginning to unravel the genetic basis of medical conditions such as cancer, heart disease, alcoholism, diabetes, and mental illness. It is evident that the study of human genetics can provide tangible contributions to our well-being, illuminate the range of human potential, and provide insights into the place of *Homo sapiens* in nature's astounding array of unity and diversity.

DNA technology has been used to improve the food we eat, determine paternity, detect disease, and convict criminals. In the span of 40 years we have learned how to predict the sex of unborn children, to diagnose many genetic disorders prenatally, and to genetically engineer products to treat or prevent disease. Human embryos can be produced by fusion of sperm and eggs in a laboratory dish and be transferred to the womb of the natural or surrogate mother. Scientists correct many genetic defects by inserting copies of normal genes into cells to supplement or replace defective ones. Human genes can be inserted into animals, creating transgenic organisms, or cloned in bacteria, which in turn produce human proteins.

Science, Technology, and Society

New career opportunities in medical genetics and biotechnology continue to emerge. The supply of recent graduates trained in genetic counseling has not kept pace with the demand for more than a decade. Projections for the next 20 years indicate that there will be hundreds of unfilled jobs in medical genetics, biotechnology, and

related research. The California State Chancellor's Office for Community College Education has indicated that by the year 2000 the biotechnology industry in California may be looking for a technically trained labor force of 60,000 or more. Biotechnology and its impact on plants, animals, humans, business, ethics, and legislation are the focus of a chapter in *Megatrends 2000: Ten New Directions for the 1990's*, by John Naisbitt and Patricia Aburdene. Community college educators are in a position to encourage those students interested in careers within this growing field that offers almost certain potential for employment.

Why Study Human Genetics?

Educational research supports the premise that comprehension and motivation increase when students perceive the relevance of what they are learning. When promoting a course in human genetics to students, colleagues, or administrators, one could cite the following:

- ♦ Genetics is one of the most exciting and rapidly advancing fields in biology.
- ♦ Studying human heredity and reproduction is more relevant than studying fruit flies and garden peas.
- ♦ An understanding of human genetics promotes a sense of personal responsibility for health by focusing on the interaction of genes and the environment.
- ♦ Human genetics education can generate appreciation for variability and encourage tolerance of human diversity.
- ♦ Rapid advances in genetics are creating a gap between the informed public and professional geneticists. A basic level of understanding is essential if personal and societal decision making is to keep pace with advancing technology.

Genetics Education at Delta College

The phrase "Build it and they will come," from the movie *Field of Dreams*, best describes the chain of events leading to the current status of genetics education at Delta College. The program has grown from a single course in human genetics to include multiple course offerings, a pre-biotechnology curriculum, presentations to local and national groups, and genetics conferences and workshops.

Genetics Courses

The biology curriculum at Delta College includes several genetics courses, from introductory courses for nonmajors to a specific course designed for students interested in a career in biotechnology. These courses include:

Human Genetics. A non-lab science elective that introduces students to human genetic principles and issues. Enrollment is open to biology majors, nonmajors, and nursing students.

Heredity and Sexuality. Designed for the honors program, this dual-enrolled course introduces both honors and nonhonors students to human heredity, sexuality, and the ethical implications of expanding scientific knowledge via lecture, laboratory activities, case studies, and field trips.

Introduction to Biotechnology. This provides a more detailed look at cell and molecular biology, including an overview of the three laboratory applications essential to biotechnology: recombinant DNA, protein purification, and cell/tissue culture. Designed for students with some background in biology and chemistry who are interested in careers in biochemistry, medicine, molecular biology, or biotechnology.

Research Project in Science. An interdisciplinary course designed to provide science students with the opportunity to design and carry out a science research project under the supervision of a faculty adviser. Interested students may elect to conduct research related to Mendelian or molecular genetics.

Pre-Biotechnology Curriculum

Delta has worked out an articulation agreement with Ferris State University (FSU), which offers a bachelor's degree in this discipline. Students completing the pre-biotechnology curriculum at Delta receive an associate in science degree, which prepares them to transfer to FSU and enter the biotech program as a junior.

A biotechnology advisory committee provides professional insight into the development of the pre-biotechnology curriculum. The committee includes local professionals working in the biotechnology industry, area high school teachers, and representatives from Ferris State University's biotechnology program as well as Delta College faculty, administrators, and counselors. The group defines the educational program, identifies resources and employment opportunities in the region, and suggests marketing strategies for the program.

Ways to Enhance Genetics Courses

Students benefit from exposure to the science of genetics through field trips to clinical genetics centers or visits to academic or industrial research laboratories. The personal impact of genetic disease becomes more relevant when delivered by the mother of a child with Down's syndrome or a person affected by neurofibromatosis. A sense of accomplishment can be achieved by facilitating student involvement with volunteer organizations such as the March of Dimes.

Beyond the Classroom

One of the most rewarding aspects of establishing a successful program in genetics education is sharing this timely information with others. Faculty members in the genetics program have provided in-service sessions to area high school teachers, served as mentors for high school teachers and other community college faculty members, and made presentations to schools and community groups.

Final Thoughts

While genetics courses have not commonly been part of the traditional community college biology curriculum, at many institutions they are becoming part of the future. Our growing knowledge in genetics is expanding the need for scientific literacy, providing new career opportunities, and promoting a better quality of life. The task of pointing out the promise and limitations of genetic research and increasing public awareness of the ethical implications of the genetics revolution is a significant one, and a growing number of community colleges are poised for the challenge.

Selected Resources

The genetics revolution has spawned a range of educational resources for bringing genetics to the classroom.

Print

Blazing a Genetic Trail, From Egg to Adult, and Blood: Bearer of Life and Death are reports in a series from the Howard Hughes Medical Institute published to chronicle the rapid progress being made by biomedical researchers; they are available free of charge upon request from Howard Hughes Medical Institute, Communications Office, 6701 Rockledge Drive, Bethesda, MD 20817-9866.

Videotapes

The Secret of Life, a videocassette series. Educators may purchase the entire series of eight programs for \$695 or individual programs for \$90 each from: The WGBH Collection, P.O. Box 2053, Princeton, NJ 08543, (800) 828-WGBH.

Internet Sites

(Thanks to Jon Hendrix, Professor of Biology at Ball State University, for sharing his extensive list of Internet URLs.)

alces.med.umn.edu/VGC.html. Genebank and search tools for molecular biologists.

kumchttp.mc.ukans.edu:80/instruction/medicine/genetics/homepage.htm. Kansas University Medical Center, Genetics Education Center homepage.

raven.umnh.utah.edu/. Hands-on genetic applications for students.

www.biotech.iastate.edu/. Biotech Education home page.

www.biotech.wisc.edu/index.html. University of Wisconsin Biotechnology Center.

www.gdb.org/rjr/history.html. Classic papers in genetics.

www.gene.com:80/ae/. Access Excellence, national education program sponsored by Genentech, Inc.

www.homepage.holowww.com. Gene Therapy Weekly.

www3.ncbi.nlm.nih.gov/Omim/searchomim.html. Online Mendelian Inheritance in Man.

www.ncgr.org/ncgr/HGP/. National Center Genome Research: What Is the Human Genome Project?

10

Chromosomes: Crucial Road Maps for Molecular Genetic Studies

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Abstract: A knowledge of the structure and function of chromosomes leads to a better understanding of many biological concepts, such as genetic abnormalities, disease, and even the aging process. This paper outlines some fundamentals, including historical and current research developments, to be considered in a basic study of chromosomes. BB.










Relevant disciplines: biology, genetics

Introduction

Knowledge of the structure and evolution of chromosomes is important for understanding the genetics of prokaryotes and eukaryotes, including humans. This knowledge has enabled scientists to locate and isolate genes, characterize them, and modify and insert genes to refraction in live organisms.

The movie *Jurassic Park* is fiction, but recombinant DNA research has progressed to the point that it is possible to transfer successfully genetic material from one organism's chromosomes to another's and to manipulate nuclear material without any reference to the original chromosomal context. James Watson and Francis Crick didn't even keep track of what species supplied the DNA for their analysis.

Many functional characteristics of genes can be understood fully only in the context of their position within a chromosome, parental or species origin, or their associated regulator gene or genes. The organizational format for results of the Human Genome Project is a set of 24 chromosome maps: 22 autosomal chromosomes and the gender-associated X and Y chromosomes. Try to memorize the symbols associated with each of the following letters:

A = , B = , C = , D = , E = , F = ,
G = , H = , I = 

This is difficult to do until the same set of symbols is put into context:

A	B	C
D	E	F
G	H	I

Historical Highlights

Early cell biologists used numerous techniques to study cells. The nucleus absorbed positively charged dye molecules more readily than any other cell structures. The term *chromosome* was generated when it was observed that cells undergoing division showed this dye most strongly on the long rodlike structures. *Chromosome* means "colored body." Fruit flies (of the genus *Drosophila*, meaning "waste loving") are used in genetic research because they have salivary glands with unusually large chromosomes. They include up to about 2⁹ (approximately 1,000) copies of the normal DNA and are relatively easy to see when stained. In 1904, Thomas

H. Morgan of Harvard discovered that wingless fruit flies were consistently missing a specific band in one of the four pairs of giant salivary gland chromosomes. This was the first visual observation that chromosomes had something specific to do with genetic inheritance. In 1910 and 1916, he and a student also were able to demonstrate that some eye color genes were located on the X chromosome. In 1933, Morgan was awarded the Nobel Prize in biology for his chromosomal genetic discoveries.

In 1953, Watson and Crick were awarded the Nobel Prize for their one-page paper on the three-dimensional, helical structure of DNA. Because DNA typically has a 36-degree angle of rotation per base pair, every 10 base pairs make a complete 360-degree turn. Thus, in 3,000,000,000 base pairs there are 300,000,000 complete turns that have to be dealt with in a 24-hour cell duplication cycle. Because a cell's chromosomes unwind to duplicate and rewind during cell division, one of two things must happen: Either the intact chromosomes complete an average of more than 20,000 revolutions per minute, or the chromosomes break into sections to complete this and the sections subsequently recoil and rejoin before completing chromosome separation. This chromosome rearrangement system, originally known as Breakase and Repairase (now Topoisomerases), provides a mechanical basis for major chromosome rearrangements such as crossover at metaphase I of meiosis and transposable genetic elements and chromosome fusions.

Plasmids and temperate bacteriophages are common transposable genetic elements in prokaryotes. Barbara McClintock studied mosaic corn for many years. In 1931, she announced that a spontaneous transposition of genetic elements in chromosomes of mosaic corn caused the mottled individual kernels. It took many years for her colleagues to recognize the validity and significance of her discoveries. She was finally awarded the Nobel Prize for medicine in 1983. Transposons are sections of DNA that undergo transposition within chromosomes. Geneticists have learned that transposons are significant in both prokaryotic and eucaryotic molecular biology. Transposons in plants and animals are highly similar to, and probably derived from, retroviruses. These RNA-containing retroviruses (such as leukemia or human immunodeficiency virus [HIV]) make DNA copies of their RNA and incorporate it into the host's chromosome. Retroviruses may also be related to the origin and regeneration of telomeres, the terminal ends of chromosomes.

Mitochondrial DNA

Mitochondria in eucaryotic cells were discovered to have relatively small (16.6 kilobase) circles of bacteria-like DNA. There are thousands per eucaryotic cell. They carry some genes; are easy to clone; do not have many complicating structural, organizational, and regulatory histone proteins; are easy to separate on a gel; and undergo relatively rapid rates of evolutionary change. They are inherited only from the mother's egg. So to understand the evolutionary genetics of both male and female mammalian lines and be able to detect past hybridization, it is necessary to understand the maternal mitochondria and the small, male-gender-determining Y chromosome. The remainder of the genetic package is the mixed chromosomal heritage from both parents.

Current Public Awareness

The public is gradually becoming aware of the role that genetic manipulation plays in their lives. In May 1994, the first food with recombinant DNA was introduced to the grocery store, Calgene's Flav'r Savr™ tomato, which can be allowed to ripen on the vine because it retains its firmness much longer than typical tomatoes, which soften too quickly when ripe.

Phenylketonuria, or PKU disease, is a defect in the body's ability to degrade the amino acid phenylalanine. Failure to restrict this amino acid in the diet of infants and young children with this genetic defect can cause mental retardation. Newborns are typically given a blood test for this condition. Nutrasweet™ (Aspartame) is a two-amino acid microprotein (aspartic acid and phenylalanine) used for sweetening low-calorie diet foods, especially diet drinks. It carries a warning on the package it comes in because of its 50 percent phenylalanine content and its potential impact on anyone with PKU. It is synthesized chemically but could be readily synthesized biologically with an initiator codon, two amino acid codons, and a termination codon.

Chromosome Structure and Function

A knowledge of the structure and function of chromosomes leads to a better understanding of many biological concepts, including genetic abnormalities, disease, and even the aging process. The following represent some of the more important biological fundamentals to be considered in a basic study of chromosomes.

Chromosome Banding

Stained chromosomes show bands that are reminiscent of the familiar bar codes used to identify products at checkout counters. There are also internal bar codes that identify whole species and genders of organisms. The zebra is an obviously externally bar-coded animal. The chromosomes consist mainly of two types or states of chromatin: (1) heterochromatin (different or dark staining), which is tightly packaged sections of relatively inactive DNA that are high in A:T base pairs, and (2) the lighter-staining bands, called euchromatin bands, which are less tightly packaged and more genetically active because they contain most of the functional genes. Euchromatin bands have a higher G:C base pair ratio.

Centromeres

A centromere is a section of chromosome rich in A:T bases to which spindle fibers attach to separate the chromosome pairs during cell division. In basal branches of various phylogenies, chromosomes commonly have attachment points for spindle fibers near one end in order to separate the chromosome pairs during cell division. As chromosomes fuse, they typically do so at their short ends. These fused chromosomes have spindle fiber attachment regions near their centers. Thus, they are called centromeres. Extra centromere regions need to be either deleted or inactivated or else the spindle fibers would tend to form competing attachment locations and tear the chromosomes apart, with major genetic consequences.

Within these chromosomes are sections of spacer DNA called microsatellite DNA, usually located near terminal centromeres. This spacer DNA is made up of repetitive series of base pairs, commonly three base pairs. In the various species of apes it shows a progressively longer series of trinucleotide repeats. Humans have the longest segments of these microsatellite genes. They account for about 5 percent of all our DNA (Glausiusz, 1995). At least seven human diseases are associated with unusually long trinucleotide repeats, including Huntington's disease and fragile X syndrome. Both are due to excessive cytosine-adenine-guanine (CAG) repeats (Welsh and Smith, 1995). The length of the repeat series commonly increases in successive generations, and the severity of these diseases is typically related to the triplet repeat size.

Telomeres

The ends of the chromosomes are known as telomeres. In all classes of vertebrates they are composed of the same sequence of six nucleotides, TTAGGG. Thus, this sequence also has been conserved for about 500,000,000 years (Moyzis, 1991). In humans, telomeres are typically composed of about 250 to 1,500 six-base repeats. Because the chromosome replication mechanism does not copy all the way to the end of a chromosome, part of it is lost at each mitotic replication and restored during meiosis. Most cells quit dividing when the last of the telomere is lost. After the expendable telomeres are gone, if the cell continues dividing, the chromosome shortening process begins to remove parts of the terminal genes on chromosomes at each division, and eventually, when crucial genes are damaged, the cell dies. Addition of TTAGGG telomere sequences during cell division could help prevent this from happening. Some cancer cells seem to be immortal and have been shown to replenish their telomeres after division (Greider and Blackburn, 1996). If this replacement of nongene DNA at the chromosome tips could be selectively suppressed, it might be a therapy against cancer cells. On the other hand, stimulating replacement could increase cell line longevity. The telomerase enzyme is a type of reverse transcriptase (RNA → DNA) system.

Chromosome Maps

Searching the human genome can be compared to a long-distance road trip through 23 or 24 states. At a scale of 1 millimeter/base pair, the genome length would equal 3,000,000,000 millimeters, or 3,000 kilometers, or 1,860 miles. Imagine looking for a briefcase-size section of unique antiparallel centerline road striping. And because of bidirectionality of DNA, both sides of the road centerline would have to be checked, and the length to be searched doubles to 3,720 miles.

Locating a gene can be an equally formidable task. With an estimated 3,000,000,000 bases (per side) and approximately 65,000 genes located on 24 types of chromosomes (22 numbered autosomal chromosomes and the X and Y chromosomes), it still means that there are about 46,000 base pairs for each gene and intervening nongene spacer DNA called introns. Thus, good chromosome "road maps" of the known genes in the 3,000,000,000 base pairs on the 24 types of chromosomes with an average of 125,000,000 bases and 2,800 genes each are the crucial reference tools to locate, study, and use the genetic code.

Visual Prospecting

Fireflies' luminescent compounds and jellyfish's fluorescent protein are useful for visually studying genetic development. Embryonic development regulator genes in fruit flies are referred to as homeotic, or HOM, genes. They are arranged on the chromosome in the same sequence as the body parts whose development they control (Radetsky, 1992). By splicing in a luminescent or fluorescent gene in the appropriate location it is possible to study the time sequences of gene function. After finding this class of genes in fruit flies, researchers used them as probes to look for equivalent genes in mice. They found the same class of gene in mice; it also codes for developing eyes. The gene for producing eyes is one of the development regulator genes that in vertebrates are called homeobox, or Hox genes.

This eye gene has also been found in eyed mollusks (Quiring, et al., 1994; Gould, 1994). These are phyla of animals that have been separate for at least 500,000,000 years. And the genes are still performing the same function. In fact the whole package of HOM genes for development of body parts in fruit flies have Hox chromosomal counterparts in mice. They are organized in the same sequence on the chromosomes: anterior body parts coded for first on the chromosome, middle body parts coded for by the next organizer genes, and the posterior body parts coded for by the terminal genes in the sequence (Radetsky, 1992).

Sometimes these regulator genes are not continuous sequences of bases of DNA but instead contain crucial regions separated from each other by seemingly inactive DNA. Sometimes the active sites are located about 10 bases apart (or some multiple of 10) because they are exposed on the same side of a 10 base per turn helical chromosome coil.

Chromosome Painting

Once a gene has been identified and isolated, it is possible to label it with fluorescent or luminescent genes or radioactive marker dye and use it as a probe to search any cell's entire genome for its location (or locations) in other organisms. Radioactive markers allow photographic searching with X-ray film. Fluorescent dye allows visible, real-time chromosome searching for marker genes. Permanent nonfluorescent dyes to paint and visualize whole chromosomes or selected portions with standard microscopy have been developed and licensed commercially (Tucker, et al., 1992). Just as bar codes are mechanically read with lasers at the checkout counter,

painted chromosomes lend themselves to similar technological automation.

Microscans and Surgery of Chromosomes

With the pulsed field gel electrophoresis technique, it is possible to elongate and microscopically visualize and manipulate entire chromosomes moving in an agar gel. And by attaching specific genetic probes color labeled with either fluorescent or normally visible dyes, individual sections of elongated DNA can be specifically labeled and viewed with a microscope (Beach, et al., 1988). It may even be possible to develop a scanning microlaser that could read chromosome base sequences "on the fly."

Plasmids and Artificial Chromosomes

Plasmids are circular pieces of DNA. They are common in bacteria. They are functionally equivalent to eucaryotic chromosomes. A eucaryotic host cell with known genetics and a DNA vector big enough to permit the insertion of large sections of eucaryotic chromosomes are needed to study chromosomes more effectively. The yeast genome is rapidly being deciphered. Isolated genes, or even large sections of any organism's chromosomes, can be inserted into yeast cells' chromosomes. Alternatively, the discrete genes can be equipped with the appropriate chromosome replication code, a centromere for genetic segregation, restriction sites for easy cutting and splicing, antibiotic resistance genes for selection, lactose metabolism genes for visual recognition by metabolic products produced, end cap telomeres, and so forth. Such artificially modified or fabricated yeast chromosomes are known as yeast artificial chromosomes, or YACs. They can be cloned in endless quantities using the mass-production technology of the brewing industry. Because these genes are typically expressed and yield a protein product, the gene function can often be easily and safely studied in yeast cultures. Useful products such as growth hormone or insulin can be mass-produced this way.

X Chromosome, Genes, and Gender

Nearly all calico cats are females. In female mammals, one of the two X chromosomes, which often carry the genes that determine any coat color, are inactivated on the margin of the nucleus early in embryonic development (Maxson and Daugherty, 1985, pp. 127-128). An inactivated X chromosome was first observed by Murray Barr in neurons of a female cat in 1949. An inactivated X chromosome is named a Barr body for its discoverer.

An autopsy report on an Olympic athlete who had

been awarded a gold medal about 50 years earlier in a female event listed the deceased person's gender as male (Maxson and Daugherty, 1985, p. 128). This and gender change operations pioneered in Sweden caused the Olympic committee to adopt a genetic gender test for athletes. It is not a physical exam but is a stained cell examination to look for Barr bodies characteristic of XX female genotype and an inactivated X chromosome (Walker, et al., 1991).

For mammals the XY chromosome gender-determining mechanism is nearly universal, with organisms that receive a Y chromosome being male and those with two X's and no Y being female. Because this is so uniform in placental and marsupial mammals, scientists wonder what else is identical in vertebrates, mammals, and primate chromosomes.

Primate Chromosomes

In 1982, Yunis and Prakash published photographs of Giemsa-stained, late-prophase chromosomes of the great apes and humans at the 1,000-band stage. The chromosome banding patterns are highly similar. But inversions and translocations have altered the symmetry of the chromosomes. Comparisons of the bar code patterns allow extrapolation back to a single pattern, presumably of the original genetic package for our common hominoid ancestor. These translocations are powerful mechanisms for generating genetic incompatibility, isolation of populations, production of new species, and tracing phylogenies.

The Human Genome Project is organized into research teams based on the chromosomes. The Human Genome Report Card maps use chromosome banding patterns defined in 1971. The maps are slightly different from those of Yunis and Prakash because they are based on a slightly different time of chromosome staining. The information pours in so rapidly that the computerized genome database, Online Mendelian Inheritance in Man (OMIM), is updated daily and is publicly available via Internet-computer access. Students can search by chromosome number or gene.

Chromosome Mutations

Because of the redundancy of the genetic code, there are up to six triplet codons coding for the same amino acid. Changes from one of these redundant codons to another do not change the amino acid sequence code and are commonly considered neutral. In a type of muscular dystrophy caused by an abnormality of chromosome 15, the

only noticeable difference in the normal and dystrophic genes of individuals is one seemingly insignificant base change at codon 624 for glycine (GGC → GGT). These are commonly regarded as neutral synonymous codon mutations. However, the change from C to T generated a new non-neutral chromosome cut (restriction) site and resulted in a defective protein that was 44 amino acids shorter than normal. Thus, it is necessary sometimes to examine the functional genetic code in the broader context of the chromosome structure.

Conclusion

Incorporation of DNA for chromosomal Matrix Attachment Regions onto the ends of the genes being transferred has resulted in much higher rates of gene incorporation and expression. Someday, when we more fully understand how chromosomes are built and function, perhaps we will be able to accomplish the now mostly hoped-for genetic modifications of the organisms in our world. In the meantime, we can develop more techniques for DNA manipulation and chromosome analysis, learn more about chromosomes, and debate what genetic manipulations are practical, ethical, and worth doing.

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11

Transgenic Crops: New DNA in Your Food

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Abstract: Transgenic crops are an emerging product of the genetics revolution. This paper includes a discussion of the types of crops being produced, the types of modifications being considered, and the surrounding debate. The role that community colleges will assume in educating both their students and the community at large about transgenic crops is addressed. Community colleges can have a major role in this debate because they are not engaged in research and development of these new technologies and therefore should not be perceived as biased.

Relevant disciplines: introductory biology, genetics, microbiology

Introduction

George Gilder begins his book *Microcosm* with a description of what he calls the quantum era. Contrasting the quantum era with the preceding era, the industrial age, he writes, "The industrial age managed and manipulated matter from the outside, . . . [however] the quantum era manipulates matter from the inside, adapting its inner structure to human purposes." The genetics revolution is a part of the quantum era. With the ability to isolate DNA and make specific rearrangements, genetic engineers manipulate genomes, the inner code of life, to serve human purposes.

A new wave of products that will emerge from the genetics revolution and will have an impact on society as a whole will be transgenics, or bioengineered foods. As this technology becomes available for the consumer, the community college can be a source of accurate and unbiased information about the new foods. To fulfill this important role, biology instructors at community colleges must be prepared to answer several important questions about transgenics.

The Role Community Colleges Play

Three groups of students are served by community colleges like Midland College: the transfer student, the vocational student, and the community at large. All three groups will have an interest in transgenic crops.

Transfer Students

The majority of transfer students enroll in general biology courses, and many may wish to pursue careers in biotechnology. Opportunities are opening up in research and development, in business, and in law, particularly in the area of patent protection. Community colleges provide the academic foundation for future research scientists and for professionals prepared to deal with the ethical, legal, and social issues related to the Human Genome Project.

Vocational Students

The vocational student is working toward certification in a particular area. One area gaining increasing attention is biotechnology. Other vocational fields that will experience the most immediate impact from transgenic crops include veterinarian and agricultural sciences and nursing. These students need exposure to the concept of transgenics.

The Community at Large

The community at large may have little interest in transgenics until a new food reaches stores. The moment the transgenics are available and consumers have to make a choice, a lot of interest will be generated quickly. Community college biology instructors should be prepared to answer the following questions for the community of consumers: What are transgenics? What specific modification is on the shelves? How was the modification achieved? Is there any danger in consuming this transgenic? The laboratory exercise in Appendix 11-2 (page 62) can be used to demonstrate the concept of transgenic plants. It is appropriate for a general biology course.

What Are Transgenics?

Transgenics are plants that have been genetically altered using recombinant DNA technology. With these techniques, genes from a foreign source, or DNA from the plant itself, can be modified and inserted into the plant. The resulting transgenic will then express new properties.

It is estimated that within the next five years there may be as many as 150 transgenic products on the market (see Appendix 11-1, page 61). To date, there are at least four transgenic crops available. The most notable is the Flavr Savr™ tomato from Calgene, Inc. This is sold as MacGregor tomatoes in stores in California, Florida, and Illinois. The tomato is genetically engineered so that it will ripen significantly more slowly than traditional tomatoes.

The other available crops are designed to give farmers improved yield and lessen their dependence on costly and potentially dangerous chemical pesticides. The Freedom II™ squash from Asgrow Seed Co. has resistance to viral infection. Boll Guard™ cotton from the Monsanto Co. is engineered to resist some leaf-eating insects. And, Roundup-ready™ cotton, also from the Monsanto Co., is engineered to tolerate recommended levels of the Roundup™ herbicide.

What Modifications Are Possible?

The types of modifications that are possible are limited only by our imagination. The types of modifications that are achievable are limited by the technology available. Modifications may be possible in nutrition, aesthetics, bioremediation, and mineral mining. This report explores a few areas, including nutritional enhancement, quality control, pest and herbicide resistance, and neutraceuticals.

Nutritional Enhancement

The compelling problem that drives efforts to achieve transgenic crop technologies is the need to improve the nutritional properties of food sources. Many crops are deficient in an essential nutrient. For instance, soybean is low in lysine and corn is low in methionine, both essential amino acids. A goal of transgenic technology is increased levels of these essential nutrients. One of the early efforts in the area of soybean improvement used a gene isolated from Brazilian nuts that, when inserted into the soybean, increased the lysine concentration. The effort is still being pursued by several groups of scientists that are achieving significant and stable increases in lysine concentration, not only in soybeans but also in canola (see Appendix 11-1, page 61).

Quality Control

The quality of the foods available for consumers is a powerful commercial goal. To this end, the Calgene Co. developed the Flavr Savr™ tomato. The polygalacturonase gene, involved in tomato ripening, was isolated by genetic engineers. The gene was then rearranged so that it could be inserted backward into tomatoes. When this new gene is inserted into the tomato plants, an mRNA molecule is produced that is complementary to the normal, or wild type, polygalacturonase gene. Before the mRNA can be translated by the ribosomes, the two complementary mRNA strands anneal together. The double-stranded RNA is not translated. In this way the ripening process is slowed significantly and tomatoes arrive at market in better condition.

There are also potential impacts in some of the oldest biotechnologies—for instance, the production of beer. In a review of the biotechnologies in brewing, McElroy and Jacobson (1995) identified at least 10 opportunities for biotechnology in the malting and brewing process. For example, increases in glucose levels will improve the fermentation step of brewing. One way to achieve this is by limiting the expression enzymes that digest glucose. The focus for barley transgenics would be to limit the expression of dextranase.

Pest and Herbicide Resistance

Pest and herbicide resistance are modifications designed to improve the farming industry, both economically and environmentally. Improved yields with lower pesticide and herbicide costs will increase profitability for farmers. At the same time, a decrease in the use of chemical pesticides and herbicides will help protect the environment.

Three major pests annually plague farmers: insects, viruses, and fungi. Resistance to each can be achieved. To develop plants that carry their own insecticide, genetic engineers have made use of leaf-eating caterpillars' natural pathogen, the bacterium *Bacillus thuringiensis* (Bt). Bt produces a substance that is toxic to the insect. Traditionally, Bt endospores have been sprayed on greenhouse crops. The caterpillars ingest the endospore where it germinates within the caterpillar's gut and releases its toxin, causing the caterpillar to lose water and die of dehydration. Genetic engineers have isolated the gene for the Bt toxin. Inserting the gene into the crop allows the control of the caterpillar without the use of bacterial endospores.

Viral resistance is achieved in a similar way. However, in this case, instead of expressing the toxins of a natural enemy to the virus, the plant actually expresses viral protein. Viruses are particles of protein and nucleic acid. The nucleic acid has genes that will encode the coat protein. Studies of viral infections have determined that for some viruses, once one viral particle has infected a plant cell all other viral particles of the same species are excluded. This exclusion is achieved by the expression of protein by the viral particle in the host cell. Genetic engineers have made plants resistant to some viral species by isolating the viral gene for the exclusion product and inserting it into the plant.

Efforts are now under way to engineer plants to be resistant to fungal infection. The cell walls of fungi are made of chitin. Genetic engineers are studying the possibility of giving plants a chitinase enzyme. Expression of this enzyme would enable plants to destroy fungi.

Another agriculturally important modification is the development of herbicide resistance in plants so that weedy species in the same field can be destroyed. One method is to modify the molecule in the plant that the herbicide targets. The target molecule can be modified in two ways: It can be rendered insensitive to the herbicide, or it can be overexpressed. As an example, the EPSP synthase (5-enol-pyruvylshikimate-3-phosphate synthase) enzyme has been identified as the target molecule of the Roundup™ herbicide. Monsanto scientists have discovered that overexpression of the EPSP synthase gives plants tolerance to levels of Roundup™ recommended for killing weedy species.

Neutraceuticals

This next possibility, the production of neutraceuticals—food sources that can serve medicinal purposes—is some years away from being a reality. A medicinal property can be genetically engineered into a plant. Work in this area was first reported by a research team directed by Dr. Charles J. Arntzen at Texas A & M University, whose research produced the viable expression of a bacterial antigen in a potato (Haq, et al., 1995). When pieces of the potato were fed to mice, the immune systems of the mice produced antibodies against the antigen.

For human consumption, the problem with expressing the antigen in a crop such as potatoes is that people usually cook potatoes before they eat them and would thus ruin the neutraceutical affect. Arntzen's team looked for a plant, such as a banana, that is eaten raw to express an antigen. The team from Texas A & M was the first to report expression of a foreign gene in a banana (May, et al., 1995).

Later in 1995, a research team from Dupont reported expression of a rabies antigen in transgenic tomatoes. If appropriate levels of expression can be achieved, these tomatoes could be used to immunize wild animals that act as reservoirs for the rabies virus.

What Are Potential Problems?

The farming community and consumers are deeply involved in an active debate about whether transgenic crops should be used, and if they are used, how they should be treated. Both groups seek accurate information about the risks and benefits of transgenic technology. The potential benefits have already been discussed. Areas of potential risk include both environmental and consumer concerns.

Environmental Concerns

A problem farmers have faced since agriculture began is the evolution of pest populations to avoid the defenses used to fight them. This problem will not go away with the use of transgenics. Traditional plant breeding has been successful in selecting and breeding plants that carry resistance to pests from existing populations. Emerging biotechnology means the selection of useful genes will no longer be limited by hybridization barriers. The pest population will, however, continue to evolve to avoid the effects of the new defense gene. It is not likely that scientists will develop any anti-evolution gene that will prevent the pest from changing to meet the new challenge.

The debate centers on two concerns: costs and environmental impact. The costs must be measured in terms of funding for research and development and how these correlate with perceived increases in the quantity or quality of the new crop.

Second, transgenic technology could result in widespread use of one specific resistance gene. In *The Last Harvest*, Paul Raeburn (1995) points out the potentially disastrous effects of losing diversity within a crop. The clearest historical example is the corn blight of 1971, in which the genetic uniformity of corn allowed one pest to nearly wipe out the year's crop.

Two other areas of environmental concerns to be addressed as transgenic crops begin to be used in field conditions are gene flow and new virus production. Crops such as squash, canola, and sunflower are capable of breeding with wild relatives. The potential therefore exists for new genes to be transferred into a wild population through gene flow. The area of concern is the impact a new gene may have on the ecology of wild plant populations.

A phenomenon known as viral recombination occurs naturally when two viral particles infect the same cell. These new viral strains can threaten plant and animal life. The frequency of viral recombination is limited by the frequency with which two species of viruses can infect the same cell. The concern is that by inserting viral DNA of one viral species into all the cells of a plant, viral recombination frequencies will increase significantly.

Consumer Concerns

The purpose of inserting recombinant DNA into plants is to give them new and better properties. Although engineers of the new technology may feel comfortable about the changes, consumers must be educated about what the changes are, the benefits to be achieved by the change, and the potential risks. Changes in the food supply must meet several consumer demands to be accepted because consumers place more importance on the values

attached to food than on scientific assessment of risks from technological change.

A clear example of consumer response to new technologies applied to food production is the rejection of bovine growth hormone (BGH) in milk production. Milk is a staple in many diets, and anything that is added to it should increase the nutritional value for the consumer. For this reason, addition of vitamin D is acceptable to most milk consumers. In the case of BGH, no increase in nutritional value was achieved. In fact, some consumers perceived BGH as a pollutant added to milk production to help line the pockets of the milk producers. The argument that BGH did not ruin the milk was of little consequence. BGH did not increase the value of the milk and was therefore rejected by the consumer.

Consumers seek objective sources of information. Community colleges can have a major role in this debate because they are not engaged in research and development of these new technologies and therefore should not be perceived as biased. At the same time, community college biology instructors are familiar with the concepts that are involved in the technologies and are practiced in the art of teaching these concepts to nonscientists.

Summary

Transgenic crops are at the crossroad that all emerging technologies encounter: acceptance or rejection by a generation of people. Both the computer and nuclear energy came to this point. Seeing that the benefits far outweighed the risks, our generation accepted computers. On the other hand, nuclear power was deemed too risky by our generation, even though future generations may decide otherwise. The time for this generation to decide about transgenics is close at hand. Community colleges will play a role in this decision if they serve as a source of unbiased, accurate information on which to base a decision.

Appendix 11-1 Bioengineered Foods under Final Consultations with the FDA¹

TYPE OF MODIFICATION	SPECIFIC MODIFICATION	CROP	COMPANY
I. Nutritional enhancement			
	Oil profile altered	Canola	Calgene, Inc.
II. Quality control			
	Improved ripening	Tomato	DNA Plant Technology
	Improved ripening	Tomato	Monsanto Co.
	Improved softening	Tomato	Zeneca Plant Science
	Modified ripening	Tomato	AgriTope, Inc.
III. Pest resistance			
	Insect (Bt) protection	Corn	Ciba-Geigy Corp.
	Insect (Bt) protection	Cotton, Potato	Monsanto Co.
	Coleopteran resistant	Potato	Monsanto Co.
	Lepidopteran resistant	Corn, Potato	Monsanto Co.
	Lepidopteran resistant	Corn	Ciba-Geigy Corp.
	Virus resistant	Squash	Asgrow Seed Co.
IV. Herbicide resistance			
	Bromoxynil	Cotton	Calgene, Inc.
	Glyphosate	Canola, Cotton, Soybean	Monsanto Co.
	Glufosinate	Canola	Agrevo Canada, Inc.
	Phosphinothricin	Corn	Agrevo Canada, Inc.

¹ From FDA Web site, www.fda.gov/.

Appendix 11-2 Inheritance in Transformed Plants¹

Note: Unauthorized release of transformed plants is prohibited. All materials should be autoclaved after use before discarding.

Introduction

Transgenic crops are traditional crop plants that have been modified using recombinant DNA technology. The insertion of new or foreign DNA or modified DNA from the original crop results in the expression of new genetic traits. In 1995, the first commercial transgenic crop, the Flavr Savr™ tomato was made available to the public. The Flavr Savr™ tomato is designed to take longer to ripen than unmodified tomatoes. Other transgenic crops are now being produced to be sold to the public.

In this lab exercise, seeds will be tested for the presence of an antibiotic resistance gene that has been inserted into the parent plant. The new gene was inserted via a process called agrobacterium-mediated transformation. An attenuated agrobacterium is able to insert a gene into plant cells. A selectable marker is used to select individual plant cells that have received the new gene. In this lab the selectable marker is the antibiotic gene. The presence of the gene in seedlings will result in different growth patterns.

Materials

- ◆ three antibiotic selection plates
- ◆ marker pencil
- ◆ latex gloves
- ◆ approximately 100 sterile seeds each of three genotypes: P1 wild type (WT), P1 transformed (T), F1 progeny (P)
- ◆ sterile toothpicks

Procedure

Week 1

1. Label the bottom of each of the antibiotic plates with one of the following; WT, T, or P.
2. Using the sterile toothpicks and sterile technique, place the sterilized seeds on the media.
3. Store the plates at room temperature and in room lighting for one week.

¹ This lab exercise was developed by Randy Allen and Sheryl Schaky for use in a genetics course at Texas Tech University.

Week 2

4. Observe and record differences in the growth of seeds in the plates labeled WT and T.
5. Record the following observations from the plate labeled P.
 - (a) The number of seedlings that resemble the growth of WT.
 - (b) The number of seedlings that resemble the growth of T.

Student Observations

1. Record the observed growth on the WT plate.
2. Record the observed growth on the T plate.
3. Record the number of seedlings with growth similar to WT and T.

Calculate the ratio of each using the formula below:

$R = \frac{\text{Number of seedlings that resemble one parental type}}{\text{Total number of seedlings on plate P}}$

Teacher Preparations

The lab makes use of seed of a plant transformed with one of the many available antibiotic resistant marker genes. These may be available at a university involved with this type of research. At present transformed seeds are not available from educational supply companies. The growth of three sets of seeds are analyzed on growth media containing an appropriate antibiotic. Non-transformed (wild type) seeds will have impaired growth on the media. Transformed plants will grow well on the media. The third set of seeds is a combination of seeds with and without the resistance marker. The seeds are the result of a F1 cross of a parental transformed plant. This set of seeds should show the 3:1 Mendelian ratio of resistant to susceptible seeds.

Objectives and Laboratory Procedure

At the end of this lab, students should be able to:

1. Describe how a selectable marker can be used to distinguish between transformed and nontransformed plants.
2. Explain the inheritance of genes in transformed plants.
3. Explain the importance of transgenic plants.

Types of Antibiotic Plates

There are several antibiotic resistance genes that are available for use as selectable markers in transformed plants. The antibiotic added to the growth media will be

determined by the resistance gene that is transformed into the seeds used in the lab. What is given below is a protocol used to make 1 liter of Kanamycin selection growth medium.

In a 2L Erlenmeyer flask mix 850 ml of distilled water with 4.33 grams MS salts growth medium and 1 ml B5 vitamins. Bring the pH of the solution to 5.7 with 1N potassium hydroxide. Bring the volume of the solution to 1L with distilled water. Add 2 grams Phytigel. Cover the top of the Erlenmeyer flask with a piece of aluminum foil fastened with autoclave tape. Autoclave the medium at 250 C, 15 psi, for 25 minutes.

Allow the medium to cool to about 50 C and add 5 ml of Kanamycin (Sigma # K 0254) stock solution (50 mg/ml) to give a 250 g/ml working concentration. Pour the medium into petri dishes and allow it to polymerize. The medium can be stored in a refrigerator for about two weeks. Allow the medium to warm to room temperature before placing seeds on it.

Seed Preparation

Seeds must be surface-sterilized before they are placed on the growth medium. Seed are surface-sterilized by submerging seeds in a 1 percent bleach solution for 5 minutes, followed by 3 rinses in sterile distilled water. The seeds are then set to dry in a clean undisturbed place in the lab. (*Note:* Be sure the seeds are fully sterilized and that students use sterile technique when plating the seeds on the medium.) The time required for the seedlings to germinate is long enough for bacterial and fungal contaminants to grow as well.

Expected Growth of Seeds on Antibiotic Plates

WT seeds: These seeds do not carry antibiotic resistance. The seedlings may not germinate on the antibiotic growth medium. If seedlings do germinate, their growth will be stunted and the cotyledons will appear pale green or yellow.

T seeds: These seeds will have been transformed with an antibiotic resistance gene. The seedlings should germinate on the antibiotic growth medium. The seedlings' growth should appear vigorous with green cotyledons.

P seeds: During transformation generally only one gene will be inserted into one site of the plant's genome, leaving empty the site on the homologous chromosome. The result is a heterozygous individual (r/+) with one resistance allele (r) and one null allele (+). The P seeds are the F1 generation resulting from the self-fertilization of a transformed plant; (r/+) X (r/+).

Punnet Square

$$(r//+) \times (r//+)$$

	r	+
r	r//r	r//+
+	+//r	+//+

The Punnet square shows the expected genotypic ratio that would result in a 3:1 phenotype ratio of transformed (resistant) to wild type (susceptible) seeds, respectively.

Safety considerations: After the lab has been completed, the media plates with all the seedlings should be autoclaved at 250 C, 15 psi, for 25 minutes. Unauthorized release of transgenic plants is prohibited by law. The autoclaved materials are safe to discard.

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12

Incorporation of the Human Genome Project into a Human Genetics Course for Allied Health Fields

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Abstract: Students in the allied health professions must be introduced to various aspects of the Human Genome Project and helped to understand how new genetic information and technologies will influence medicine in a technical way. They should also consider the moral and ethical consequences of this information. To accomplish these goals in the classroom, several activities, as well as print and electronic resources, can be used. An annotated list of resources is provided.

Relevant disciplines: genetics, biology

Introduction

Considering the varied and broad teaching demands on faculty in community and small colleges, it is often difficult to remain current on topical research areas; the field of human genetics is a good example of such an area. The rapidly advancing pace of the discipline, coupled with its complex technology, can be intimidating to even the most seasoned faculty member. The contributions of the Human Genome Project to the increasing breadth of the discipline make the task even more daunting. The genes associated with various genetic diseases are being identified in increasing numbers, making it possible for physicians to diagnose presymptomatically genetic disease and offer either preemptive treatments or a greater range of reproductive choices. New genetic technologies not only will influence medicine in a technical way, but also will force the public into moral and ethical dilemmas, one of which is the possibility of genetic discrimination in health care coverage. It is imperative that students entering the health professions be introduced to the various aspects of the HGP. The HGP and related genetic advances can be incorporated into a human genetics course for students in the allied health professions.

Classroom Activities and Assignments

Although all aspects of the HGP will have an impact on the medical field, two out of the 11 project areas are of particular interest to students entering the allied health professions. These two areas are disease gene identification and the ethical, legal, and social implications of the project.

Genetic Disease

Information on disease gene identification can be introduced into the classroom effectively through the use of the Human Genome poster from the *Journal of NIH Research* (see Resources in Print and Video, page 67). This poster provides information on the mapped sites of approximately 1,000 genetic disorders. Sites that have been mapped within the previous year are highlighted.

To investigate mapped diseases, students in the Human Genetics course at Kent State University–Stark Campus are required to select a particular disorder that is mapped and located on the Human Genome poster and write a term paper discussing various aspects of the disease. This paper includes a summary of disease signs, symptoms, mode of transmission, incidence, and a dis-

cussion of in utero testing, or presymptomatic diagnosis. To complete the assignment, students must address various options, including preconception or pre-implantation screening, therapeutic abortion, gene therapy, or medical management of the disease. Often students will select a particular disease that has affected either a member of their families or an acquaintance. Students approach the paper with tempered enthusiasm and more often than not end the project with quite a sense of accomplishment. When resources to research a disease effectively are not available in journals and books on campus, information usually can be found online.

Students share information with each other in a discussion forum and invite questions regarding aspects of the individual diseases. The discussion often leads to the areas of reproductive choice or medical management of the disease. Students summarize key aspects of the disease they report on using the front of a three-by-five-inch index card. The cards of all students are then arranged on paper and photocopied, providing each student with a copy of an up-to-date, succinct resource on genetic disease prepared by classmates.

Genetic Disease Testing

With testing available for cystic fibrosis, fragile X syndrome, Gaucher's disease, retinoblastoma, familial adenomatous polyposis, and Huntington's disease, as well as several other diseases, most students question why at-risk individuals are not taking advantage of the full battery of available genetic tests. The cost of genetic testing in both monetary and emotional terms, as well as the futility of testing for diseases for which there is no treatment or cure, is always a topic for lively discussion. Most important, students learn that finding the disease gene or mutated form of a gene via testing does not necessarily mean that the patient will eventually manifest the disease.

Although testing seems to be a recent development, testing and registries for Tay-Sachs disease, such as Dor Yeshorim, have existed for several years. The idea behind the registry is to prevent young adults who carry the gene from becoming involved in a relationship and eventually having affected children. This service is considered by some to verge on the edge of eugenics, but it is praised by others for effectively lowering the incidence of this deadly disease in a susceptible community. With controversial attempts to map the genes for obesity, violent behavior, hyperactivity, or even homosexuality, there is concern and a need for classroom dialogue on parental use of genetic testing to screen offspring for desirable or undesirable traits in utero.

Gene Therapy

As a consequence of disease gene identification, gene therapy protocols are becoming more common. Approved protocols include treatments for alpha1 anti-trypsin deficiency, cystic fibrosis, familial hypercholesterolemia, and Gaucher's disease. Treatment of adenosine deaminase (ADA) deficiency was the first gene therapy protocol approved and is one of the few protocols that has demonstrated some degree of success. *The Secret of Life* video series by David Suzuki presents the case of Ashi DeSilva, the first recipient of gene therapy, in a most interesting and understandable manner. Portions of the eight-part video series are used throughout the semester to augment lectures of various applied genetics topics (see Resources in Print and Video, page 67).

Genetic Legislation and Health Insurance

In addition to diagnosis and treatment, the other area of medicine to be affected by the HGP will be that of health care insurance, particularly in the area of "preexisting conditions." Use of genetic data or history by insurance companies to deny coverage or charge excessive rates will effectively void any good that could be derived from genetic research. It is the charge of the National Institutes of Health-Department of Energy Working Group on Ethical, Legal, and Social Implications (ELSI) of the Human Genome Project and the National Action Plan on Breast Cancer to formulate a series of recommendations for local and federal policymakers such that broad discrimination in health care coverage due to a family history of genetic disease will not become a reality. Since the HGP was launched in 1990, eight states, including Ohio, have enacted legislation to protect patients with genetic disease from health care insurance discrimination. Students from Ohio are required to investigate the extent of the state's law by writing to their state legislators with any questions and concerns they may have regarding the law and its shortcomings. If the student receives a reply, it is shared with the class.

A role-playing activity concerning health insurance can raise several interesting issues about genetic privacy laws and the insurance industry. A scenario concerning Huntington's disease and a patient, employer, family, physician, and insurance company's right to know provides the basis for the activity. Members of the class adopt various roles in the scenario and then provide a panel discussion addressing genetic privacy, medical, and insurance issues from the point of view of their role.

Resources in Print and Video

Students can find many books and periodicals in their libraries with excellent articles and extensive information on the HGP. In addition, there are many resources available for little or no charge. Some of them are listed here.

Human Genome News, a free publication of the Human Genome Management Information System (HGMIS). Subscribe using the HGMIS home page on the World Wide Web (see Internet Addresses, page 68) or by writing HGN, Oak Ridge National Laboratory, 1060 Commerce Park, MS 6480, Oak Ridge, TN 37830. It is a quarterly newsletter with information on all aspects of the HGP, including updates on mapping and sequencing, personnel and genome research center changes, relevant publications in various journals, technology, and information on grants and sponsored programs.

The Scientist, a newspaper with short, easy-to-read articles. Subscribe by writing The Scientist, P.O. Box 10525, Riverton, NJ 08076. It covers subjects ranging from the discovery of the BRCA-1 gene to the winners of the Nobel Prize for Physiology or Medicine. A research section uses data from the Institute for Scientific Information's *Hot Paper Database* to provide information on recent trends in basic and medical research.

Genetic Engineering News (GEN), a publication of Mary Ann Liebert Inc.; subscribe by writing GEN, 2 Madison Avenue, Larchmont, NY 10538. This focuses on technological developments of new gene products and industrial applications of genetic technology; it provides succinct reports on biotechnology advances in both plant and animal medicine.

Newsletters of biotechnology supply companies, such as *Strategies in Molecular and Cell Biology*, a publication of Stratagene (La Jolla, CA 92037). These free newsletters are directed at research laboratories considering the purchase of the company's products but are generally informative and contain diagrams and schematics that can be used in the classroom. They provide the latest information on equipment, reagents, and techniques being used in the HGP.

The Human Genome Poster is available for a nominal charge at Genome Poster, The Journal of NIH Research, 1444 I Street, NW, Suite 1000, Washington, DC 20005.

The Secret of Life, a video series by David Suzuki. This is an eight-part video series produced in 1993 by WGBH in Boston in conjunction with the BBC; it

addresses many genetic topics, including the first case of gene therapy protocol, genetic engineering, control genes and development, and the search for disease genes.

Resources on the World Wide Web: Home Pages

With the explosion of electronic information, it is now possible for anyone to obtain cutting-edge information and technology on a routine basis. The World Wide Web provides inroads into databases and information that previously could be obtained quickly and easily only at large research universities. The Web also provides an interactive format for students. Students can acquire information as well as become involved in online discussions (see Internet Sites, page 68).

The Human Genome Management Information System for the U.S. Department of Energy Human Genome Program offers online viewing of *Human Genome News*, information on training and educational resources, updates on recommendations and reports of the Ethical, Legal, and Social Implications (ELSI) committee, a related publication list, and public documents; project information can be requested online. The page also lists educational resources, including videotapes, newsletters of genome centers, and information and a calendar on HGP outreach and educational workshops.

The journal *Science* produces a genome issue each fall and in 1995 offered an interactive discussion of genetic discrimination in health insurance.

The American Medical Association allows searches of genetic disease and links to many other resource sites.

The Federal Drug Administration provides up-to-date information on biologics, human drugs, and pending technology.

Online Mendelian Inheritance in Man (OMIM) provides information on the medical and molecular aspects of genetic disease.

Information for Genetics Professionals at the University of Kansas Medical Center provides links to many other sites and to genetic disease support groups, genetics education resources, genome centers, and more.

GenBank notes all known protein and nucleotide sequences of humans as well as plant and animal genomes, and genetic counseling scenarios.

Exploratorium's "Diving into the Gene Pool" site is a forum for public discussion of the ethical, legal, and social implications of the HGP.

Scheduling of Activities and Summary

Students should have a thorough understanding of basic genetic concepts, including DNA transcription, translation, mitosis, meiosis, mapping, and linkage before undertaking a discussion of the Human Genome Project. During a 15-week semester, approximately three weeks, or six 75-minute lecture periods, are spent discussing various aspects and applications of the Human Genome Project.

Experience at Kent State University–Stark Campus demonstrates that through the use of writing assignments, role playing, videotapes, class discussions, printed resources, and electronic information systems, it is possible to provide students in a human genetics class with a thoughtful, current discussion of the various aspects, implications, and possible consequences of the Human Genome Project.

Internet Sites

www.aaas.org/science/science.html. *Science*.

www.ama-assn.org/. American Medical Association.

www.exploratorium.edu/genepool/scenario_1.html. Exploratorium.

www.exploratorium.edu/genepool/scenario_3.html. Exploratorium.

www.fda.gov/. U.S. Food and Drug Administration.

www.kumc.edu/GEC/prof/geneprof.html. Information for Genetics Professionals, Kansas University.

www.ncbi.nlm.nih.gov/. GenBank.

www3.ncbi.nlm.nih.gov/Omim/. OMIM.

www.ornl.gov/TechResources/Human_Genome/home.html. Human Genome Management Information System.

13

Integrating Genetic Knowledge into Community College Nursing Education

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Abstract: The faces of health and disease have been changed by advances in genetics. New discoveries abound, yet old issues, especially ethical ones, are still important. This paper highlights the influence of genetics across the life span, in common diseases and in drug therapy. It indicates how genetic content can be integrated into community college nursing courses and suggests roles for nurses in genetics.

Relevant discipline: nursing

Introduction

While new discoveries and techniques in the field of genetics affect the way health and disease are now viewed, many of the basic principles of genetics still hold, as do the old genetics-related ethical, social, and political concerns. These concerns may be viewed in the context of recent knowledge to provide a new perspective on older concerns. The political issues that influence health care in the United States are ones that are also important in disorders with a genetic component. These include issues of privacy, confidentiality, and discrimination on a genetic basis. Of particular concern are basic human rights: individual rights versus the rights of family members, the rights of society versus the rights of the individual, and who owns and controls genetic information. Genetic information may be a consideration in issues surrounding suicide and the termination of life or pregnancy.

Society needs to gain greater knowledge and appreciation about the influence of genes in common disorders such as cancer and heart disease and in human attributes such as behavior. Equally significant is an understanding of therapeutic approaches such as gene therapy; advances in fetal therapy and surgery, both in utero and extra utero; and advances in reproductive technology such as prenatal diagnosis of the pre-implantation embryo and ovum transfer.

New aspects of genetics include the sequencing and mapping of the human genome, the molecular basis of human diseases, and modes of inheritance.

Genetics across the Life Span

Within nursing curricula, genetic concepts must be included across the life span. Discussion should not be limited to the impact of genetics only in obstetrics and pediatrics courses. The following are examples of genetic disorders or disorders with a substantial genetic component that are most commonly recognized or diagnosed at various life stages.

Newborn—achondroplasia, spina bifida, cleft palate, and phenylketonuria

Infant—agamaglobulinemia, Menkes' syndrome, and many inherited biochemical errors

Childhood—Tay-Sachs disease, cystic fibrosis, and Hurler disease

Adolescence—Turner's syndrome, Klinefelter's syndrome, and acute intermittent porphyria

Adulthood—Familial polyposis coli, Huntington's disease, and autosomal dominant polycystic renal disease

In the newborn, many genetic disorders will be visible because of characteristic physical features or symptoms beginning soon after birth. In infancy, those disorders, usually biochemical, that were not immediately evident may make their appearance. In childhood, other metabolic and biochemical disorders may become evident, and in adolescence, disorders affecting growth or sexual development may emerge. Other disorders, including adult forms of typically juvenile disorders, do not usually make their appearance until adulthood. For example, Huntington's disease typically makes its appearance at 40 years of age or even later.

Integrating Genetics into the Curriculum

Genetics can be integrated into many aspects of the curriculum. General principles of inheritance and the ways genes act and interact to confer resistance or susceptibility or produce variation can be included in introductory nursing courses. Examples of genetic effects on drug metabolism can be included in pharmacology sections or courses. Material specific to adult or medical-surgical nursing, such as genetic influences in cancer, heart disease, and diabetes, can be covered in these courses, and genetic-related content applied to the community, such as screening, can be included. Material related to newborn screening, metabolic diseases, prenatal diagnosis, and much of the content on genetic counseling can be included in the maternal-child, family or obstetric, and pediatric nursing courses.

Categories of Genetic Disease

Genes and chromosomes can be thought of as etiologic agents of disease in much the same way that microorganisms are considered. Thus, genetic diseases are those that may be categorized as follows:

- ◆ Caused by one or more mutant genes. Single gene defects usually arise from genes in the nucleus and follow the typical Mendelian pattern of inheritance, although diseases due to defects in mitochondrial genes following different inheritance patterns have been identified, as has imprinting. It is important to teach the concept of allelism. Alleles are alternate forms of a gene. Thus, a given gene, gene A, may have alleles A1, A2, A3, A4, and so on, and these different forms can result in different degrees of severity, the appearance of symptoms at various times in

the life span, and other consequences. Diseases caused by more than one mutant gene at different locations are called polygenic.

- ◆ Result from aberrations in chromosomes where there is one or more extra or missing chromosomes or from changes in particular chromosomes such as deletions, additions, inversions, or translocations, or as a result of the instability or fragility of chromosomes.
- ◆ Caused by damage from drugs, chemicals, or other agents that may affect either somatic cells or the fetus directly, causing effects that may include altered growth, fetal death, congenital anomalies, or functional deficits.
- ◆ Caused by the interaction of several genes with environmental factors. These are known as multifactorial.

Genetic Components of Disease

Nursing students need to appreciate that virtually all disorders have a genetic component. In some diseases, this is more obvious than in others. Most diseases, therefore, fall on a continuum between totally genetic and totally environmental. Even some diseases that appear to be largely environmental may actually have a substantial genetic component. For example, some persons may think of bone fractures in a young adult as far toward the environmental end of the continuum. However, genetic factors are estimated to be responsible for 70 to 80 percent of the bone mass during the first 20 years of life, with the remainder resulting from nutrition, lifestyle, and so on, and it is bone mass density that influences how easily bone fractures will occur. This example also shows that environmental factors are important in their interaction with genetic factors. Thus, even a person who has bone mass of a less desirable quality from the genetic perspective can attain an average level through proper nutrition and other factors.

Taking another example, persons who have the genetic condition classical phenylketonuria inherit two mutant recessive genes for this condition and accumulate phenylalanine in their blood after ingesting food with this protein; the condition eventually leads to mental retardation and other major effects. One can imagine that if these persons lived in an environment where they never encountered phenylalanine, they would never know they had these genes. Recognizing the environmental factor, the phenylalanine, allowed treatment of this genetic disorder by the prescription of diets low in phenylalanine for at least the developmentally critical periods of life. This environmental manipulation has

resulted in preventing most of the serious mental retardation from phenylketonuria because of its inclusion in compulsory newborn screening programs across the United States.

Genes may also be involved in susceptibility and resistance. The classic example of this is the case of malaria caused by the parasite *Plasmodium falciparum*. Persons who are heterozygous for the sickle cell gene are less susceptible to the development of malaria by this parasite than are those who possess two normal hemoglobin genes.

The concept of thinking about genes as agents of disease also allows thinking about ways to modify the effects of genes. Genes do not act in isolation but act along with other genes, agents in the environment, and in the context of the person's total genetic background and internal milieu. Thus, a great degree of genetic individuality exists and, in some cases, may become obvious when this leads to symptoms or effects not seen in the general population.

Within the field of community health or public health nursing, aggregates and populations are studied. Learning ways to approach the health of populations has always been important. Needs are not universal, however. The supplementation of food such as bakery products with iron may be helpful to those who suffer from iron deficiency anemia; on the other hand, it could be harmful for those who suffer from hemochromatosis, a disorder of iron overload and storage.

Genes and Drug Therapy

Of particular interest to nurses is the interaction between genetic factors and drug therapy. This field is known as pharmacogenetics to the geneticist. People may react differently to drugs and process drugs differently because of their genetic makeup. There are two basic applications of this. The first is in those individuals who have an actual metabolic disorder, and the second is in those individuals who have a variation in enzyme levels involved in the processing of a certain drug. In either case, the defect or variation may not be apparent until the individual encounters the drug that reveals the disorder.

For example, glucose-6-phosphate dehydrogenase (G6PD) deficiency affects millions of persons worldwide and 10 to 15 percent of African Americans. Exposure to certain agents such as sulfa drugs, primaquine, dapsone, chloramphenicol, quinidine, fava beans, and other oxidants can produce hemolysis and hemolytic anemia, the severity of which depends on the percentage of active enzyme present. Some of these drugs are used to combat

the opportunistic infections seen in persons with HIV infection, and therefore particular caution needs to be taken before these drugs are administered. This information is considered part of the core curriculum in HIV nursing (Casey, Cohen, and Hughes, 1996).

The alleviation of pain is another important nursing concern. One of the drugs used in pain relief is codeine. Most of the analgesic effect of codeine results from the body's production of morphine from codeine. About 7 percent of people do not produce morphine from codeine and therefore do not receive an analgesic effect. Nurses can be taught to think about genetic reasons that patients may not exhibit the expected effect from a drug or may experience unexpected side effects.

Genetic Screening

A genetics role for many nurses in practice is in screening programs. Genetic screening has been defined as a search in a population for:

- ◆ Persons who possess genotypes that are associated with the development of genetic disease
- ◆ Persons with certain genotypes that are known to predispose the individual to illness
- ◆ Persons who are the heterozygous carriers of recessively inherited genes that in autosomal recessive disorders (in double dose) can cause genetic disease in their descendants
- ◆ Persons with polymorphisms (variations) not now known to be associated with a disease state (Committee for the Study of Inborn Errors of Metabolism, 1975).

The major types of screening are the detection of genetic disease in newborns, identifying carriers of recessive genes, prenatal detection and diagnosis, predictive and presymptomatic screening, and screening in the workplace. Newborn screening programs have scored major successes in the prevention of the effects of deleterious genes, especially in the cases of phenylketonuria, galactosemia, and congenital hypothyroidism.

Screening for carriers and predictive and presymptomatic testing have engendered major discussions about appropriate informed consent. Whether to test minors, or even permit them to be screened, for certain conditions, such as Huntington's disease, is currently being debated. Another debate revolves around confidentiality and release of information. These issues can be discussed in ethics courses and nursing classes.

Genetics and the Common Disorders

Another area that can be covered in adult health or medical-surgical nursing is the contribution of genetics to the common disorders—cancer, heart disease, diabetes, and so on. Further, care of the adult person with genetic disorders that emerged in childhood needs to be discussed. In the recent past, those afflicted with cystic fibrosis, sickle-cell anemia, and other genetic disorders died in childhood. Now that they are living into adulthood because of successful treatment, treating them for unrelated conditions against the background of their genetic disorder becomes a concern for practitioners who treat adults.

Genetics and Behavior

In the field of behavior, genetics-related research has frequently aroused strong emotional and societal responses. Some of the behavior-influencing factors in which the elucidation of a substantial genetic component could ultimately influence public policy include sexual orientation, violence, criminal behavior, and intelligence. In psychiatric and mental health nursing, the genetic contribution to such disorders as depression, panic disorders, and alcoholism can be discussed.

Nursing Roles in Genetics

What are the appropriate roles in genetics for the nurse with an associate degree? The International Society of Nurses in Genetics is in the process of developing standards of genetics clinical nursing practice at the beginning and advanced practice levels. The roles nurses play are diverse and depend on preparation, experience, and practice site. At the associate degree level they include:

- ◆ Recognizing the possibility of a genetic component in a client's health problem and taking appropriate referral action
- ◆ Interviewing clients and taking comprehensive family histories
- ◆ Planning, implementing, administering, and evaluating genetic screening programs in communities
- ◆ Evaluating clients with genetic disorders and developing and monitoring an individualized plan of care
- ◆ Assessing the cultural health beliefs and practices and family functioning of a client and the client's family
- ◆ Providing education and health teaching related to genetics

- ◆ Supporting families in the process of genetic counseling and decision making and interpreting and reinforcing genetic counseling information
- ◆ Follow-up of positive newborn screening tests
- ◆ Serving as an advocate for a client and family affected by a genetic disorder
- ◆ Coordinating care and services and ensuring continuity of care
- ◆ Managing home care and therapy (Lashley, in press)

Conclusion

New discoveries and applications in genetics as well as genetic issues influence the way health care and disease are viewed. The advances made by the Human Genome Project have emphasized the contributions of genetics to many aspects of health and disease. The ethical, legal, and social issues section (ELSI) of this project will be especially important in health care settings. Discussion of genetics and of the ethical and social policy issues that have evolved can be integrated into the associate degree nursing curriculum in many places. Nurses with knowledge of genetics can play many roles in health care. Recognizing the importance of genetics in health care and policy allows new ways to think about health and disease. Perhaps nowhere else is it as important to focus on the family as the primary unit of care, because identification of a genetic disorder in one member can precipitate detection and diagnosis in others and allow them to receive appropriate preventive measures and treatment. Nurses are uniquely positioned to combine the application of principles of health promotion and maintenance and disease prevention with an understanding of cultural differences, family dynamics, and human growth and development to deal with a client and the family unit in ways that can ensure an effective outcome.

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14

Introducing Concepts and Skills in DNA Technology

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Abstract: A series of laboratory exercises introduces students to the Human Genome Project and related skills and concepts of DNA technology. These exercises include spooling DNA strands on a glass rod, separating DNA fragments through electrophoresis, and identifying crime suspects by their DNA "fingerprints." Students gain access to the latest data on the Human Genome Project via the Internet and model gene cloning by manipulating paper diagrams of a bacterium, a plasmid, and the gene for human insulin. An equipment list is included. BB.

Relevant discipline: introductory biology

Introduction

The last 20 years have seen a revolution in biotechnology so profound that it has changed the way we think of ourselves and the world we live in. Students in the basic sciences need access to educational materials that encourage their understanding of genetics, gene manipulation, and the public policy issues that surround the genetics revolution. This series of laboratory exercises provides college students enrolled in basic science courses with the opportunity to work with models of DNA, participate in DNA purification, and discuss the ethical and social implications of the Human Genome Project.

DNA Structure and Function

James Watson and Francis Crick used model building to discover the double-helical structure of DNA; students can recreate this discovery by putting together and then manipulating a puzzle model of DNA. The DNA molecule consists of a chain of building blocks called nucleotides. Students use a nucleic acid molecular model kit containing puzzle pieces of the different nucleic acid components. The puzzle contains colored pieces that represent the deoxyribose sugar, the phosphate group, and the nitrogen-containing base. There are four kinds of nucleotides in the DNA molecule, each differing in the type of nitrogen base it contains. Students begin by assembling the four types of nucleotides found in DNA.

DNA replication is controlled by many different enzymes, known collectively as DNA polymerases. The enzymes open up the double strand of DNA at a point termed the origin. The weak hydrogen bonds between base pairs are broken, and the DNA molecule unwinds, or unzips. Four types of nucleotides are available within the nucleus and they are paired one after the other onto the exposed bases of the DNA strand. The end result is two DNA molecules, each composed of one strand of the old DNA molecule and a newly assembled strand. Saving half of the old strand and constructing a new strand alongside is called semiconservative replication. Students simulate DNA replication using the DNA nucleotides they have already constructed.

Transcription and translation occur in a cell as often as the cell has need of new polypeptides. The DNA molecule contains the genetic code in the nucleus. RNA is the molecular messenger that carries the information from DNA in the nucleus to the ribosomes in the cytoplasm. The genetic code contained in the DNA molecule

is transcribed into an RNA molecule. The code consists of three bases in a sequence along one strand of the DNA molecule. This series of three bases is called a codon. Three types of RNA—mRNA, tRNA, and rRNA—converge at the ribosome to synthesize polypeptides. Translation is the process of using the message encoded on the mRNA to link up amino acids in a specific sequence to form a polypeptide. Students put together a specified DNA sequence, create the corresponding RNA sequence, and discover the polypeptide coded for by the DNA.

Purification and Separation of Bacterial DNA

Scientists have devised techniques to isolate and manipulate DNA from many living organisms, including humans. The purification of chromosomal DNA is often the first step in recombinant DNA experiments. Students use a simple technique to purify bacterial DNA. In the presence of salt, nucleic acids such as DNA will precipitate from solutions containing high levels of alcohol. Students collect the bacterial DNA precipitate and redissolve it in a small volume of buffer. Alcohol precipitation also removes small impurities such as salts, sugars, and amino acids from the DNA precipitate. Chromosomal DNA is composed of very large molecules that form viscous clotted masses during alcohol precipitation. This material is easily collected, or “spooled,” onto a glass rod.

Gel electrophoresis is one of the most widely used techniques for separating large molecules such as DNA. During gel electrophoresis, DNA and DNA fragments move through a gel matrix because they are in a charged field. The molecules move according to their size; smaller molecules move faster and larger molecules move slower. After a period of time, the different molecules of DNA can be seen by staining with a dye.

Newer designs of electrophoresis equipment use a horizontal gel slab because it is easy for students to prepare and load with DNA. First, students prepare an agarose solution and pour the warm solution onto a glass plate. A plastic comb is placed in the solution before it polymerizes. This comb is then removed, leaving sample wells embedded in the gel. A Tris EDTA buffer is poured over the gel in a gel chamber and prepared DNA samples are loaded into the sample wells. The buffer chamber is then carefully hooked up with electrodes to a power source. An electrical charge pulls the DNA molecules

to the positive end of the gel. After a period of time, the power is turned off and the gel is transferred to a staining solution.

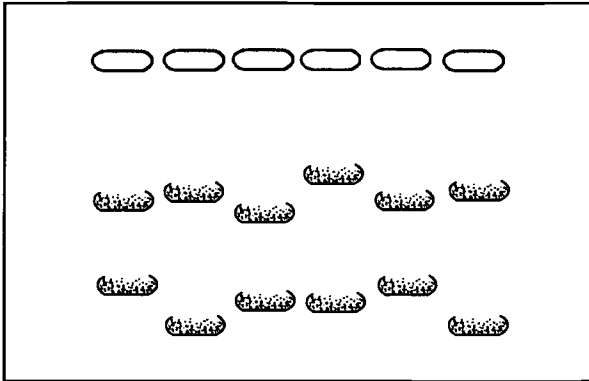
The DNA separated by electrophoresis must be stained before it can be seen. After staining, the DNA can be seen as blue bands in the gel. A DNA sample that produces a single band of blue indicates that the DNA is in one large piece. The DNA molecule is often cut into different-sized pieces before it is separated by gel electrophoresis. Enzymes called restriction enzymes will cut DNA between specific base sequences. Different restriction enzymes yield different-sized DNA fragments.

The size of students’ “unknown” DNA fragments is calculated by comparing their migration distances to a set of standard DNA fragments. The standard DNA contains DNA fragments of known sizes. The DNA size is measured in numbers of base pairs per fragment.

DNA “Fingerprinting”

Each individual’s DNA is as unique as his or her fingerprints. Identifying individuals by their DNA has proved very useful in law enforcement. The process compares DNA from hair, semen, blood, or skin found at the crime scene with DNA from potential suspects. This technique can indicate with 99 percent probability that the suspect was at the scene of a crime. No two individuals, with the exception of identical twins, will have identical DNA in their cells. Many court cases today rely on DNA evidence to convict suspects. Other applications of DNA analysis include paternity testing, prenatal screening, and screening for genetic diseases.

The first step in analyzing a DNA sample is to cut the DNA using a series of restriction enzymes. These enzymes are isolated from bacteria, and each type of enzyme will cleave the DNA molecule in a specific place. A sample of DNA that has been treated with restriction enzyme will contain different-sized fragments of DNA. This fragmented DNA is then separated on an agarose gel and the banding pattern is analyzed. Variations in the banding patterns between individuals arise because some base sequences in the DNA vary from one person to the next. Students analyze a diagram (Figure 14.1) depicting DNA “fingerprints” obtained from blood samples at a crime scene and from two suspects. They will try to link the suspect to the scene of the crime.

Figure 14.1 DNA "Fingerprint"

Ethical and Social Issues of the Human Genome Project

Geneticists use two types of maps to characterize the human genome. A genetic linkage map places genes in sequence according to their position relative to a known fragment of DNA. The second type of map is a physical map, in which researchers measure the actual physical distance between two known DNA markers. Human Genome Project investigators can use genetic linkage and physical maps to look at a large portion of DNA, such as a chromosome, or a more detailed view of a specific region, such as a gene.

Original proposals for the HGP emphasized sequencing all of the DNA in the human genome. This goal proved too costly and time consuming. Almost 95 percent of the DNA on our chromosomes is noncoding, which means it is not used to synthesize cell products. Scientists now are focusing on detailed genetic and physical maps of the 5 percent of the DNA that does code for a particular cell product. Mapping of the coding portion of the human genome is the primary goal of the HGP, with complete sequencing of the other 95 percent to follow only if the cost becomes reasonable.

One useful outcome of the HGP that has already occurred is the identification of genes responsible for genetic disorders. Recent successes include the identification of genes responsible for Duchenne muscular dystrophy (DMD), retinoblastoma, neurofibromatosis, and cystic fibrosis (CF). This knowledge has led to better diagnosis and medical treatment of these disorders.

Information on the latest gene mapping sites is available through the Internet, and students have the opportunity to gain access to this data using computers available in the laboratory.

The HGP also will allow us to compare genes found in different organisms with those found in humans. Since 99 percent of all DNA is the same in eucaryotic organisms, scientists would like to identify the specific genes that produce a mouse or a human or a plant.

Concerns about the HGP include its high cost. The project is federally funded and is budgeted at \$200 million per year for 15 years. Some people feel this \$3 billion could be better spent on other social and political problems. Others argue that coordination of the HGP is a more efficient way to conduct research in human genetics because it minimizes duplication of efforts.

Some critics maintain that diagnosing a genetic disorder when there is no treatment available for the disorder causes more harm than good. Individuals who learn that they have these disorders will be frustrated and worried about their health. Already, scientists have isolated several disease-causing gene mutations that do not yet have a treatment.

Society may be required to provide guidelines and limits as to the definition of a normal human being. Each of us should be involved in the decision, in an atmosphere of scientific inquiry and a guided discussion of the opinions relating to social and ethical issues such as this one.

Gene Cloning

Recombinant DNA technology, or gene cloning, as it is commonly called, joins DNA from different organisms. Foreign DNA can be inserted into bacteria cells using a plasmid, a small loop of DNA found in many bacteria. The segment of foreign DNA is inserted into the plasmid DNA, which grows and replicates right along with the bacteria. Since exact copies of the foreign DNA are produced, they are said to have been cloned.

In recent years, a biotechnology industry has grown out of recombinant DNA techniques. Genetic transfers are now possible in plants and animals. Crops such as tomatoes and strawberries have been genetically altered to resist pests and low temperatures, producing higher yields for farmers. A genetically engineered carp contains a gene from rainbow trout that causes the carp to grow 20 percent faster. The world population consumes increasing amounts of fish, and the faster-growing carp will help to fill the growing shortfall in offshore fish production.

Concern for the environment has been a part of the gene cloning picture since its beginnings. Scientists do not want to produce genetically altered organisms that will threaten the existence of native plants or animals. The

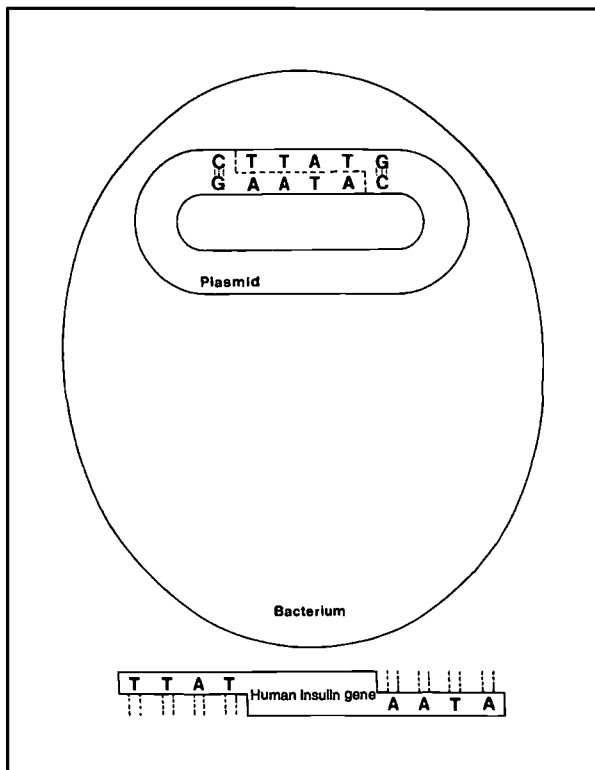
complexity of our ecosystem is something to be treasured and preserved, as it is the source of future genetic material.

One example of the usefulness of cloning is the production of human insulin in bacterial cells. Insulin is a hormone that regulates glucose levels in blood. People suffering from diabetes do not produce enough insulin and must take daily injections of insulin. Recently, scientists found a cheaper way to produce insulin using the techniques of genetic engineering.

First, the series of nucleotides that code for the production of human insulin is identified. Next, the gene for human insulin is removed from the human DNA using restriction enzymes, and then the gene is inserted into the plasmid's DNA. As the bacterial cell containing the altered plasmid grows and divides, the human gene inserted in the bacterial plasmid produces human insulin. The bacteria excrete the insulin into the liquid media the cells are grown in. Insulin is then collected and purified for human use.

In a related laboratory exercise, students cut out a paper diagram (Figure 14.2) of the gene for human insulin, cut open a paper plasmid, and then tape the insulin gene into the plasmid, matching the single-stranded nucleotide sequences from each piece of DNA.

Figure 14.2 Paper Diagram of the Gene for Human Insulin



Summary

Introducing college biology students to the basics of DNA technology is an exciting and challenging experience. This series of laboratory exercises is designed to educate students while at the same time challenging them to understand how this technology will affect their lives. These laboratory exercises introduce and then explore the social implications of the Human Genome Project. Students are encouraged to analyze and discuss the possibilities and limits of genetic research. With this introduction to DNA technology, students can then analyze and discuss the social implications of the Human Genome Project.

Equipment and Supplies

- ◆ DNA Puzzle from Carolina Biological Supply
- ◆ Paper diagram of a bacterium, plasmid, and the gene for human insulin
- ◆ DNA Spooling kit from Edvotek
- ◆ Materials for DNA spooling include test tubes, 95 percent isopropanol, 5-ml. pipettes
- ◆ Diagram of DNA samples cut with restriction enzymes and separated on an agarose gel
- ◆ Horizontal Gel Electrophoresis Apparatus and DC power supply from Carolina Biological Supply
- ◆ Size Determination of DNA kit from Edvotek
- ◆ Access to genetics databases such as gdb.com on the Internet

15

Human Genetics

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Abstract: Sickle-cell anemia and Huntington's disease are two genetic diseases used to illustrate aspects of human genetics. The pedigrees for families with these diseases show the patterns of inheritance. Genetic counseling uses the pedigree, along with prenatal or adult testing, to determine the probable transmission of the disease. Gene therapy and related implications are discussed.

Relevant disciplines: introductory biology, genetics

Introduction

In an introductory course in biology, there is limited time for any one topic. Although Mendelian and molecular genetics must be taught to lay a foundation for any advanced study, human genetics, which is inherently more interesting to students, is usually given cursory handling. The following is an expanded approach to this topic that covers both Mendelian and molecular genetics in relation to human genetics.

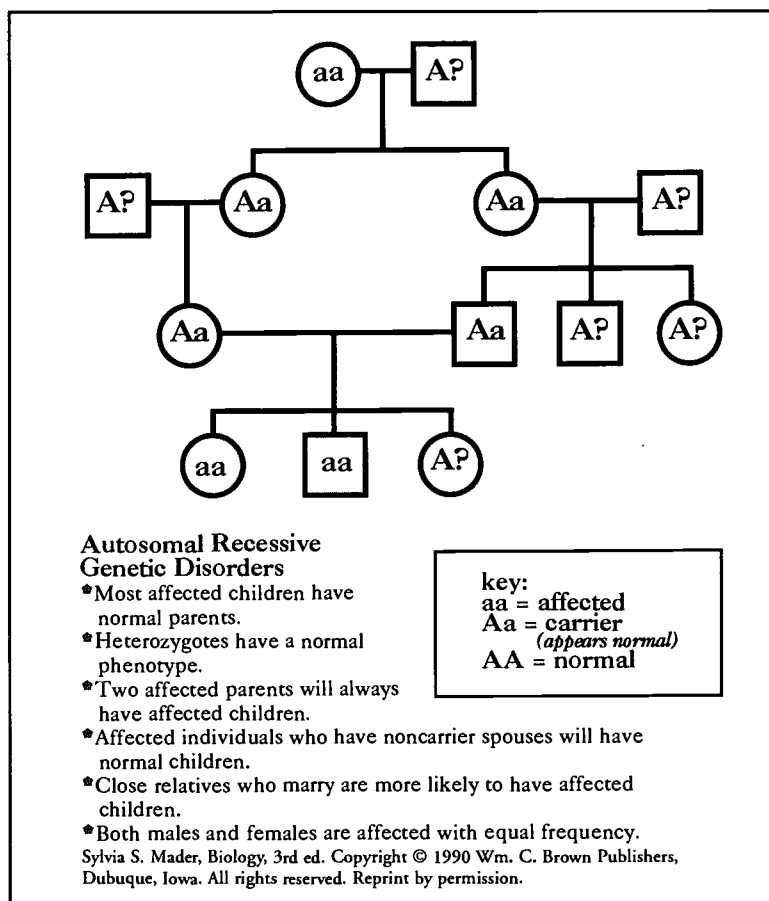
It is not possible in any course to study any great number of human traits. There are about 80,000 different genes. Some traits may be considered trivial, such as middigital hair, attached earlobes, and tongue rolling. These traits play little or no role in the mating process, and, indeed, most people are unaware of these traits even in their immediate families. Some traits, such as intelligence, body build, and skin color, can cause great concern. These traits are believed to be polygenic and are hard to quantify and trace.

Diseases represent an area of concern. More than 5,000 genetic disorders are known. Table 15.1 lists a few of these. Down's syndrome and Klinefelter's syndrome are caused by extra chromosomes; consequently, many different genes are involved. In both cases, inheritance is sporadic and does not follow any pattern. Other conditions listed in Table 15.1 show autosomal recessive, autosomal dominant, or sex-linked inheritance. Instructional units based on two of these diseases, sickle-cell anemia and Huntington's disease, will demonstrate for students the methods of study, the causes of disorders at the gene level, the methods of treatment (including gene therapy), and the possible impact on evolution.

Table 15.1 Genetic Disorders

GENETIC DISORDER	CAUSE	NATURE OF ILLNESS	INCIDENCE	INHERITANCE
Down's syndrome	Extra chromosome 21	Mental retardation	1 in 800	Sporadic
Klinefelter's syndrome	Male with extra X	Abnormal sexual differentiation	1 in 2,000	Sporadic
Cystic fibrosis	Abnormal chloride transport	Complications of thickened mucus	1 in 2,500 Caucasians	Autosomal recessive
Huntington's disease	Unknown	Progressive neurological degeneration	1 in 2,500	Autosomal dominant
Duchenne muscular dystrophy	Deficient muscle protein dystrophin	Progressive muscle degeneration	1 in 7,000 males	X-linked
Sickle-cell anemia	Abnormal beta globin	Weakness, pain, impaired circulation	1 in 625, most of African descent	Autosomal recessive
Hemophilia	Deficiency in clotting factor	Uncontrolled bleeding	1 in 10,000 males	X-linked
Phenylketonuria	Deficiency in enzyme	Mental retardation	1 in 18,000	Autosomal recessive
Severe combined immunodeficiency	Deficiency in adenosine deaminase	Absence of immune defenses	Extremely rare	Autosomal recessive
Tay-Sachs disease	Deficiency in acetylhexosaminidase	Fatty materials in brain	1 in 3,000 Ashkenazic Jews	Autosomal recessive

Figure 15.1 Autosomal Recessive Genetic Disorder



Sickle-cell anemia has been known in Africa since the 18th century and in the United States since the 19th century. It is a disease that mainly affects those of African descent. It is characterized by red blood cells that assume a sickle, or crescent, shape; this condition leads to anemia, clogging of the arteries, and interference with circulation. To counterbalance the anemia, dilation of the heart occurs. Poor circulation leads to local failure of the blood supply, causing abdominal pain, muscle and joint damage, and sometimes kidney or heart failure.

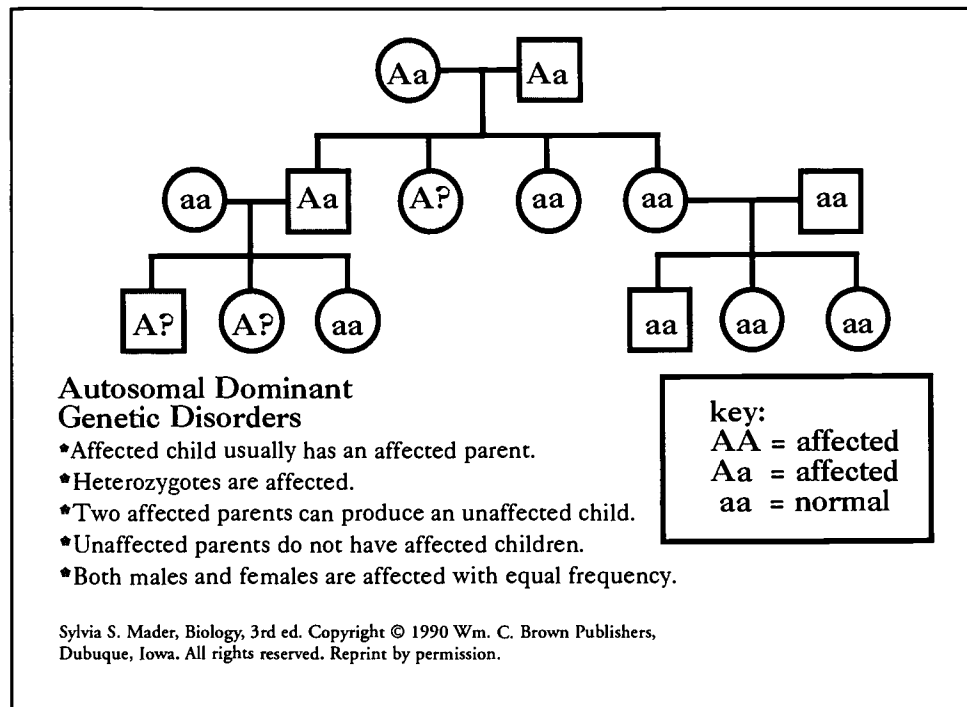
Because of the length of human life, researchers cannot follow genetic traits for several generations. Classical methods of genetics using garden peas or mice cannot be used to better understand this disease in humans. Other methods must be used. Chief among these other methods is the pedigree, a chart of the relatives of an individual and the occurrence of a specific trait in these relatives. From a presenting person, one can trace as far forward and backward as memory or records allow. Figure 15.1 presents a

pedigree demonstrating the transmission of an autosomal recessive genetic disorder.

Sickle-cell anemia is transmitted as an autosomal recessive disease. A person with the disease can have two apparently normal parents. Males and females are affected equally. Some geneticists classify sickle cell-anemia as incomplete dominant because heterozygotes that are said to have the sickling trait are recognizable under conditions of low oxygen tension or by a simple blood test.

Huntington's disease is quite different. It is transmitted as an autosomal dominant. No symptoms appear early in life. At about age 40 there is a loss of control of voluntary muscles, producing twitching and convulsions, degeneration of nervous tissue, and finally death in 10 to 15 years. Figure 15.2 shows a pedigree of an autosomal dominant genetic disorder such as Huntington's disease. It appears in every generation and affects males and females equally. Heterozygotes show symptoms of the diseases.

Figure 15.2 Autosomal Dominant Genetic Disorder



These two diseases are of great concern. In sickle-cell anemia, sufferers have crises throughout their lives and frequently die before reproductive age. With Huntington's disease, people live normal lives until early middle age and then succumb to this fatal degenerative disease. In both cases, human suffering goes on for extended periods of time. The cost of care in emotional and financial terms is extremely high. The concern beyond the affected individual is about passing the disease to one's children.

Genetic counselors can tell, based on Mendelian genetics, the probability of a couple having a child with either disease. A pedigree will show the pattern of inheritance if it is not already known. If both parties are carriers of the sickling trait, they have a 25 percent chance of having a child with the disease. If only one parent has the gene for the sickling trait, none of their children will have the disease, but there is a 50 percent chance of any one of their children being a carrier. In the case of an autosomal dominant disease such as Huntington's disease, two heterozygote individuals have a 75 percent chance of having a child with the disease. Even if only one parent has the disease, there is a 50 percent chance of producing a child with the

disease. With Huntington's disease, because of the late onset of symptoms, a couple may already have had their children before one of the parents realizes he or she is affected. When the genetic status of a person with a family history of either disease is unknown, counselors may recommend testing. It is now possible to test for many genetic diseases, including sickle cell anemia and Huntington's disease, at any stage of life from fetus to adult.

For chromosome analysis of the fetus, cells may be obtained by amniocentesis or by chorionic villi sampling. Ultrasound is used to locate the fetus, a needle is inserted into the uterus, and a small amount of fluid is extracted. This fluid contains cells with the genetic makeup of the fetus. The cells are grown in culture for a few weeks to amplify them. The necessary tests can then be done. Amniocentesis can safely be done at about the fourth month of pregnancy. Chorionic villi sampling can be done at an earlier stage (at about eight to 10 weeks). In the process, a tube is inserted through the vagina into the tissue surrounding the placenta. Cells from the chorion are removed. These cells may be tested directly.

Once the genetic status of a person is known, what can be done about the disease? At the present time, very

little. For sickle-cell anemia, supportive therapy, such as bed rest, hydration, or transfusion is the usual treatment. The only proven cure is a bone marrow transplant. This is quite risky and suitable donors are hard to find. For Huntington's disease, there is no cure. So, at the present time, knowledge of one's status can be used in deciding whether or not to have children, but it does little for the affected individual. The future does hold some hope for actually treating or curing these diseases. Gene therapy, which may involve enhancement or replacement of genes, may provide a cure for genetic diseases that are currently untreatable.

When a disease is carried by a single gene, whether dominant or recessive, it is theoretically possible to replace or supplement the defective gene with a normal gene. Genes can be transferred either into a germ cell or into somatic cells. Should this become possible, few people are likely to object to somatic cell therapy that would treat genetic disorders within the somatic cells of the affected individual. In contrast, germ line gene therapy would change the genetic makeup of the gamete-forming cells.

While gene therapy does seem to offer some hope for treating genetic disease, altering germ line genes would affect future generations and is controversial. Should it become available, individuals may elect to prevent a lethal or debilitating disorder. Any factor that alters allele frequency could have far reaching effects on the population: Evolution depends on the gene pool of the population. It is unlikely that gene therapy will reach such proportions, but the effects on allele frequency on altering the course of disease must be considered.

Approximately 40 out of every 500 African Americans are heterozygous carriers of sickle-cell anemia and one out of 500 has the disease. Thus, out of 1,000 copies of the gene, 42 will be sickle cell and 958 will be normal—in other words, 4.2 percent sickle-cell and 95.8 percent normal. Compare this with a 12 percent sickle-cell rate in Central Africa, a region of Africa that has a substantial number of malaria cases. Carriers of the sickling trait are more resistant to malaria than

either the homozygous normal or those with the disease. The allele frequency is maintained at a high level because it has a selective advantage. In the United States, no such advantage exists, and the frequency of the allele has dropped. With Huntington's disease, no advantage is known and most carriers of the disease have already produced their children before the onset of symptoms. The disease has no effect on reproductive rates or the frequency of the allele.

In most cases we do not know what, if any, advantage now or in future is attached to a given allele, so we have to consider carefully possible consequences before we eliminate any alleles. We must look at the ethical considerations of all of our knowledge of human genetic disorders. Some questions that arise are:

- ◆ Should known carriers of a lethal allele marry and have children?
- ◆ If a fetus is shown to have a disease should it be aborted?
- ◆ Should gene therapy be used to "improve" a child and not just to prevent disease?
- ◆ Germ line gene therapy affects the population; should decisions to have this procedure be private?
- ◆ Should employers or insurance companies be told of genetic carrier status?

While it may be some time before we have to answer these questions, it is not too early to begin to discuss human genetic diseases, the cures and treatments, and what they mean to our society.

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16

Multimedia Approach to DNA Teaching

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Abstract: A novel and interactive approach to the teaching of the biology of DNA has been developed utilizing computerized multimedia techniques. This program was created with the Authorware authoring program, to which scanned figures as well as video captures, classical music, and art were added; these complement the program and give a strong visual and sensory impact. A list of equipment and technology necessary for production and use of multimedia materials is provided. This program has been used by students at the Science Multimedia Laboratory at Richland College.

Relevant disciplines: introductory biology, anatomy and physiology, microbiology, human genetics

Introduction

Throughout the past 20 years, the approach and techniques of teaching biology have experienced a great revolution. From the simple use of the blackboard to color slides and transparencies prepared by the instructor, lectures have been enhanced to make a greater impact. Publishers started to supply instructors with colorful transparencies, and commercial concerns produced films and, later, videos for the classroom.

The idea that "a picture is worth a thousand words" became "an animation is worth 10,000 words." Films and videos, however, were not easily adapted to fit the needs of a class. It was difficult to select sections of either for use in a course.

After the appearance on the market of computer and multimedia systems, publishers began developing software to teach science: to allow students to review concepts in an interactive mode, to progress at their own pace, and to repeat material. In December 1993, the author was invited by leaders of a publishing company to advise them in the development of educational multimedia in biology. The analysis of commercially available material for biology revealed the lack of multimedia in this area, while the areas of chemistry and anatomy and physiology had taken the lead.

The impact and importance of the use of multimedia in education was clear. Students were arriving in college biology courses with a knowledge of computers. Software programs suitable for teaching biology to these students were not available, however; the majority of the programs were aimed at other sciences and precollege students.

Richland College has encouraged its faculty to explore the use of technology to support instruction. For this purpose, equipment, administrative support, and computer support personnel are available to its faculty. This support has fostered the development of multimedia presentations and tutorials to enhance the biology curriculum.

The DNA module described here was created as an interactive program for use by students in the Science Multimedia Laboratory. The program is also used during lecture presentations. It was prepared using the Macromedia Authorware development tool with the assistance of the staff of Richland's Faculty Support Multimedia Center.

The flexible software design enables the instructor to move through the lecture material with ease. The

Authorware development process also allows the user to add personal and creative touches to the presentation, including art, photographs, music, color, and design.

The program presents a variety of digital images, diagrams, and video clips that illustrate and facilitate the instruction of the biology of DNA. The narratives are an optional feature employed especially by students who have difficulty with reading or by students for whom English is a second language. The DNA module was burned onto a CD-ROM to facilitate its use by students in the multimedia laboratory. This program enables students to work interactively at their own pace and according to their particular needs. It also can be used by the instructor in classrooms equipped with multimedia computers and projection equipment. Students have responded with favorable comments about the program.

The following equipment and technology was used to create the multimedia approach to DNA teaching:

Hardware

- ♦ IBM 486/66 multimedia computer (16 MB of RAM) to prepare the program
- ♦ Pentium 90, Intel Smart Video Pro for video and laser disc capture
- ♦ Pentium 75, (16 MB of RAM) to capture music
- ♦ Toshiba P75 laptop (24 MB of RAM) to present the program
- ♦ HP ScanJet 2C scanner
- ♦ Sound Blaster 16 sound card
- ♦ IBM Lexmark black-and-white printer
- ♦ HP Desk 660C color printer
- ♦ Philips CDD521 CD burner
- ♦ Sharp 1650 projection panel
- ♦ Buhl overhead projector

Software

- ♦ Macromedia Authorware 3.0 authoring program
- ♦ Calgari Truspace for three-dimensional images
- ♦ Sonic Foundry Sound Forge
- ♦ JASC Paint Shop Pro
- ♦ Adobe Photoshop
- ♦ Adobe Premiere for video and laser disc capture

The Creation of a Multimedia Approach to DNA Teaching

The program consists of 55 pages or frames that contain figures, script, music, videos, and voice narrative to teach the topic of DNA biology. The introduction includes a turning double-stranded helix followed by a sculpture by Henry Moore, while the music of Mahler serves as background. The addition of music puts students into a receptive frame of mind, while frames showing the Atacama desert in full bloom provide students with a vivid understanding of the expression of dormant DNA brought forth by a rainstorm.

The main menu (Figure 16.1) provides buttons that indicate the different topics presented in the program. The buttons are color-coded and they can be activated independently to reach any of the five sections in any order.

Figure 16.1 Main Menu

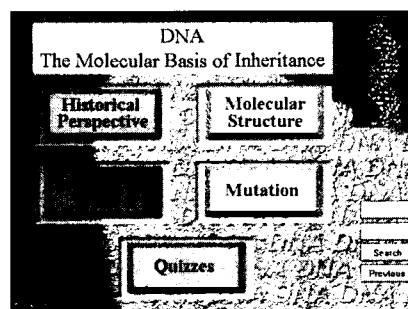


Figure 16.2 depicts the first page of the Historical Perspective section. This describes the monk Gregor Mendel's experiments with breeding garden peas. Other pages highlight Martha Chase and Alfred Hershey's work on the way viruses behave and the X-ray crystallography photos of DNA taken by Rosalind Franklin and used by Watson and Crick in their work.

Figure 16.2 Mendel's Experiments

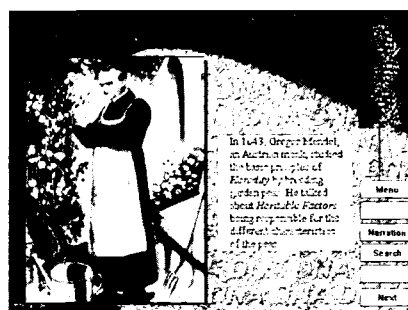


Figure 16.3 is a page in the second section of the program that describes the molecular structure of DNA. When students click on parts of the structure and bonds, the name of that structure or bond appears. Here, the student has clicked on one of the dotted lines representing the hydrogen bonds.

Figure 16.3 Base Pairs

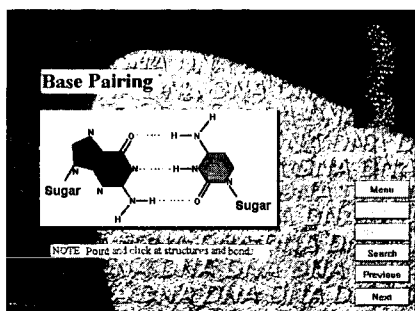


Figure 16.4 shows an example of a question presented in the Quizzes section. Students select an answer to the question and receive instant feedback. After clicking the answer, comments appear in color-coded rectangles for the correct or wrong possibilities. In the example, the student selected an incorrect answer.

Figure 16.4 Quiz Sample

Considering the Multimedia Approach to DNA Teaching

The reaction of students to this program has been extremely positive. The following are the principal benefits for students:

- ◆ Presentations are more engaging and challenging.
- ◆ Laboratory work is individualized and self-paced.
- ◆ Concepts can be explained in detail and repeated as needed.

- ◆ Every page is interactive. Students click the search button, enter a word to search for, and a list of pages that contain the word appears.
- ◆ Material is relevant to the college and class because the instructor is able to apply personal touches to the program.
- ◆ The narrative button provides special help to students with reading difficulty and to international students, who can learn the pronunciation of new words.
- ◆ The music in the program helps students relax and be more receptive to new concepts.

The development of materials is a learning process for the instructor, who becomes acquainted with the latest technology for computerized instruction. The process, however, makes many demands upon the developer. The following are necessary:

- ◆ Many hours for planning and creating programs and considerable amounts of patience and tenacity
- ◆ Supportive administration and colleagues
- ◆ Funding for costly equipment and software
- ◆ A team of computer experts to guide the creator of the program
- ◆ Overcoming the intimidation and fear of learning new techniques

Summary and Conclusion

This novel and interactive approach to teaching the biology of DNA has been developed utilizing computerized multimedia techniques. This program, available to all faculty and students in biology classes at Richland College through the Science Multimedia Laboratory, gives a strong sensory perception of the science of genetics.

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17

Discovering Genetics through Field Trips

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Daley College, Illinois

Abstract: The basic concepts of genetics and biotechnology can be learned from lectures and textbooks; however, students discover the excitement of scientific inquiry through interactive learning. Students participate in four off-campus field trips and keep a diary that contains analyses of relevant journal articles, daily five-minute writings, and homework based on the Nova video series.

Relevant discipline: introductory biology

Introduction

Daley College is an urban community college, one of the City Colleges of Chicago. The annual enrollment is approximately 5,400 commuter students, most of whom work part-time or full-time while attending college. Their average age is 31.

Between nine and 12 hours of laboratory science are required for an AA or AAS degree. The second semester of freshman introductory laboratory science includes a six-week unit on human genetics.

As part of the course, students keep a personal log or diary of journal articles and TV, news, or magazine articles concerned with human genetics. They write an evaluation of these materials in nonscientific terms and explain the scientific ramifications apparent in each article. The course includes laboratory exercises in which students isolate DNA; do electrophoresis of hemoglobin; and study the Southern blot test, Barr body analysis, PKU (Guthrie test), and the evolution of blood groups using *E. coli*. A six-week unit also includes development of a medical family pedigree chart and field trips to the Midwest National Archives, Mt. Sinai Hospital genetics laboratory, Misericordia House, and the University of Chicago.

A Family Medical Pedigree and the National Archives

Students visit the Midwest National Archives, located across the campus from Daley College, to learn how to gather documents and use military records, census figures, and immigration papers to determine their family pedigrees. In addition, they interview relatives to gain information on birth and death certificates, marriage licenses, and military documents. Through these interviews they gain knowledge of family longevity, family illnesses, birth defects, education, and occupations, which they document using classic genealogy charts.

Students trace the maternal or paternal side of the family for four or five generations and present their health pedigrees to the class in chart form. Discussions that follow focus on health risks and patterns of inheritance. Students' presentations are videotaped for self-assessment and to provide examples for future classes.

Students have written relatives in Mexico or Poland for information. Others have obtained baptismal records because vital statistics were destroyed during a war. One student wrote to a prison to obtain confirmation of a marriage that took place there. Some have family Bible histories.

Sometimes a family's oral history contradicts the recorded information. A student may learn from the family that a relative was hospitalized with cancer, while the death certificate shows cause of death as "nosocomial" or "pneumonia."

If a death certificate of a relative states the cause of death as coronary heart disease, a student may do more research to determine whether death was due to hypertension, coronary occlusion, a stroke, congestive heart failure, or a valve problem. This research increases the accuracy and value of their charts, to the greater benefit of themselves and their children.

One student who had received a diagnosis of ovarian cancer took her pedigree to her oncologist and showed him the trend in the maternal side of her family for ovarian cancer. Another student shared a family wedding portrait with the class and noted that the three generations of women in the picture exhibited the symptoms of strabismus.

The research of one 24-year-old student showed her family had a predisposition for type I diabetes. The student noted that the severity was increasing while the age of onset of diabetes was diminishing in the family: Her grandfather received a diagnosis of type I diabetes at 45, her father at 35, and she at 24.

Mt. Sinai Hospital Reproductive Physiology Lab

A field trip to the Reproductive Physiology Laboratory of Mt. Sinai Hospital allows students to observe in vitro fertilization and genetic screening by karyotyping. This field trip serves a second purpose because students use the occasion to discuss career opportunities with genetics technicians, counselors, and professional staff. The trip to Mt. Sinai Hospital is the impetus for lively class discussions on gene therapy and in utero surgery.

Upon returning to campus, students participate in laboratory exercises related to genetic screening. They use paper reproductions of karyograms of genetic defects and analyze the defect depicted as Turner's, Klinefelter's, or Down's syndrome.

In another laboratory exercise, they test for the Barr body using cheek cells stained with Methylene Blue. They discuss how the Barr body test was used in the Olympics to screen female participants.

Misericordia House

A field trip to Misericordia House was incorporated into the course to allow students to observe and interact with children of all ages who have birth defects, fetal alcohol syndrome, trauma damage, and cocaine dependency. One is able to see how many of the Down's and Turner's children are capable of being semi-independent and that the personality and feelings of the individual are never disabled. Even the profoundly disabled receive computerized education, physical and occupational therapy, and fit in at some level in the community structure at Misericordia. This opens discussion on the value of life, abortion rights, and the "children having children crisis" in our society.

Students research the physical and physiological problems of genetic disorders, focusing on longevity, reproductive potential, and statistics of transmission of the birth defects. The tour also allows students to discuss genetic impairments with the nursing director as well as prescribed therapy, treatment, and medications.

University of Chicago

Students participated in the Genetics and the Law symposium at the University of Chicago in early January 1996. They heard arguments about whether prenatal testing should be done, who should have access to this information, and why many families have testing done under a pseudonym. Rebecca Eisenberg, one of the principal speakers at this symposium, discussed the Human Genome Project, patients, and the role of insurance companies.

Nova Videotapes

Position papers are written on topics covered in the Nova videotapes viewed in the classroom. These include:

- ◆ Huntington's chorea
- ◆ Fragile X syndrome
- ◆ Murder, rape, and DNA
- ◆ Cystic fibrosis
- ◆ Sickle-cell anemia

Students watch the Huntington's chorea tape and discuss the attitudes of the individuals in the video with a genetic history of Huntington's. Next, they watch a 15-minute tape by Joseph Josephson on ethics in the 20th century. Students then are asked to reevaluate their opinions. One student's "before" and "after" responses, concerning a

celebrity who carried the gene for Huntington's disease, are typical:

Student response before viewing ethics video:

Even if [he] did know that he had Huntington's, there is nothing he can do about it. There is no cure for Huntington's.

Response after viewing video:

As far as [the carrier] is concerned, I believe he was unethical in bringing four children into the gene pool. He knew there was a good chance of his offspring being afflicted with Huntington's disease, yet he still had children.

Conclusion

Students invariably discuss the tapes, materials, and field trips with parents, siblings, and friends and bring their input into the follow-up discussions. These discussions

include every shade of social and cultural bias in the community. The role of the teacher is to keep the discussions scientific and nonjudgmental.

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18

A Combination of Laboratories in Biotechnology Demonstrating the General Approach of the Human Genome Project

Joan McCoy-Messer
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Abstract: Community college instructors may incorporate the intricate technical information that describes the Human Genome Project into beginning college courses by using laboratory activities that use articles familiar to students. These hands-on learning experiments used to illustrate the project's general approach take the mystery out of science. BB.

Relevant discipline: introductory biology

Core Curriculum Related to the Genome Project

A molecular genetics curriculum usually covers the flow of genetic information from DNA to RNA to proteins. This approach to the material, however, may not be the best method of making the subject meaningful to all students. A better understanding of molecular genetics can be provided to students who have little or no background in molecular laboratory techniques. A number of simple laboratory activities have been developed that require minimal equipment while targeting enhancement of biology core knowledge. These laboratory activities use materials familiar to students and, consequently, take the mystery out of science. The end product is students who "do science" rather than memorize scientific concepts. Students will be able to relate to the techniques used in the genetics revolution because of their own experience in working with similar, albeit elementary, laboratory methodology. These hands-on learning experiences illustrate the practicality of allowing students to work with the major macromolecules of genetic importance. Each of these laboratory experiences fits into the two-hour time slot generally allowed for laboratory exercises.

The following three related laboratory exercises focus on molecular technology:

- ◆ Partial purification of the enzyme peroxidase from garden radish
- ◆ Isolation of genomic nucleic acid from onion (Brown, 1990)
- ◆ Analysis of DNA and protein purification by agarose gel electrophoresis

Partial Purification of the Enzyme Peroxidase from Garden Radish

The first macromolecule introduced in this laboratory is an enzyme, a catalytic protein that speeds up chemical reactions. The enzyme, a peroxidase, analyzed in this laboratory comes from the common garden radish. Purification of the peroxidase from radishes has been documented in the literature (Maehly, 1969), but in this exercise there will only be partial purification of the enzyme. Students will be able to note the difference in the enzyme activity between the partially purified enzyme and the original extract.

After grinding the radish with a kitchen blender, the cellular debris is removed by filtration using a coffee filter. Exogenous proteins are removed by salt precipitation. Aliquots from each stage of purification are assayed for

peroxidase activity. In the third laboratory, these aliquots will be assayed for purity by agarose gel electrophoresis.

An assay system similar to this one is used by diabetics for monitoring blood glucose levels. This color strip system, which is based on the immobilized glucose oxidase, is coupled with the hydrogen peroxidase to ABTS (see Equipment List, below), a nontoxic chromogenic electron donor (Majkic, 1975; McCoy-Messer, 1993). The intensity of the green of the oxidized ABTS is proportional to the concentration of glucose in the blood. The similarities between this experiment and color strip assay systems available at local pharmacies can be discussed in this laboratory exercise. A demonstration of the “radish” assay system enables students to relate enzymes to their own lives because many are acquainted with individuals who have diabetes.

Isolation of Genomic Nucleic Acid from Onion

Isolation of genomic DNA is usually only demonstrated for students in college laboratory classes because of the need for specialized equipment and the lack of laboratory skills on the part of the student. Both of these obstacles can be overcome using the DNA spooling laboratory developed by Judy Brown (Brown, 1990). Again, common household reagents are used, including dishwashing detergents, table salt, and coffee filters. Onion is chopped, suspended in a mixture of dishwashing detergent and table salt, and heated. After cooling, the cell walls are disrupted in a kitchen blender and cellular debris is removed by filtration through a coffee filter. The DNA in the supernatant becomes visible because of the change in viscosity with the addition of ice-cold ethanol. This laboratory is popular with students and usually is “student proof” (McCoy-Messer, 1996).

Analysis of DNA and Protein Purification by Agarose Gel Electrophoresis

In the last laboratory in the series, students use agarose gel electrophoresis to see the cellular nucleic acids and peroxidase (Brown, 1990; Mader, 1994). The partially purified peroxidase obtained from radishes is compared with a commercially purchased peroxidase. Since agarose gel is a native, or nondenaturing, gel, the ABTS activity assay solution can be applied over the gel after electrophoresis to ascertain which protein bands have peroxidase activity. The students are introduced to the concept of different sizes of DNA fragments. This laboratory experience greatly enhances lecture discussions of DNA sequencing and restriction fragment length polymorphism.

Some of the questions discussed in relation to these exercises are:

- ◆ How could you pick one gene out of all the genomic DNA and get enough of just that one gene to sequence?
- ◆ Once you had the gene, how could you determine the related protein?
- ◆ How could you get enough protein to analyze in the laboratory?
- ◆ If you did not have the gene for a protein, how could you get enough protein to analyze?
- ◆ How could you obtain enough protein for analysis if (1) you do not have the gene for a protein, (2) the protein is involved in a severe human disease, and (3) there is no source for the protein other than human cadavers in which the protein is present only in meager quantities?

Summary

Questions such as these point out the efficiency of the Human Genome Project: With the gene in hand, the protein can be recombinantly expressed in enough quantities for further scientific studies. The overwhelming cost of reverse genetics (from the protein to the gene) consumes years of research time and carries an extremely high financial expense.

Involving students as active learners and using cutting-edge molecular technology result in understanding and excitement. Students' experience in laboratory-based molecular biology courses will increase their awareness of the perplexing questions and dilemmas brought to light by the Human Genome Project.

Equipment List

- ◆ onions and garden radishes
- ◆ Tris-HCl buffer
- ◆ blender
- ◆ loading buffer¹
- ◆ water bath
- ◆ ice-cold ethanol
- ◆ liquid dishwashing detergent
- ◆ distilled water
- ◆ noniodized table salt
- ◆ sodium phosphate
- ◆ coffee filters
- ◆ ABTS²
- ◆ micropipettors
- ◆ ammonium sulfate

- ♦ power supply
- ♦ microcentrifuge tubes
- ♦ agarose gel electrophoresis
- ♦ peroxidase (Sigma Chemical Chamber Co.)

- ¹ Amresco has a loading buffer with dyes that separate into bands while the gel is running. Call 1-800-448-4442 for more information.
- ² ABTS, or 2,2'-azino-bis-(3-ethylbenzthiazoline-6-sulfonate), is available from Sigma Chemical Co. and is not toxic, mutagenic, or carcinogenic.

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19

A Laboratory Approach to Molecular Genetics as an Adjunct to a General Biology Sequence and Clinical Chemistry Course

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Abstract: Biology and related applied fields are moving rapidly into the molecular realm. A series of hands-on laboratory exercises that reinforce concepts in genetics have been developed and integrated into biology and biotechnology courses at Darton College. These exercises, which demonstrate the dynamics of gene expression and acquaint students with the technologies used to study the genome in vitro, will prepare graduates from community college programs in biology and medical laboratory technology to contribute effectively to the genetics revolution. BB.

Relevant disciplines: introductory biology, medical technology

Background

Many good jobs in the advanced biomedical and biotechnology fields exist for trained laboratory personnel. According to biotechnology employers, these jobs require considerable familiarity with applied laboratory techniques as well as a knowledge of scientific theory. Consequently, the Darton College faculty has designed the curriculum to enhance the value of graduates of the medical laboratory technology (clinical chemistry) and biological sciences (biochemistry and molecular biology) programs.

Laboratory experiences are designed to provide students with knowledge and skills identified by personnel in the biotechnology industry as assets to prospective employees. These include spectrophotometric techniques; solution chemistry and pH, enzyme and protein measurement; sterile technique and culture methods; protein electrophoresis and applications; and DNA and RNA electrophoresis and applications.

Designing an Approach

The first attempt at implementing laboratory exercises designed to teach the techniques mentioned above was directed at first-year students in the medical laboratory program. Two quarters of biology and chemistry are prerequisites for entering the formal program. In a series of weekly, three-hour laboratory sessions, students received a short introductory lecture outlining the purpose and goals of the exercise and then carried out the exercise in groups of two. Students were encouraged to make notations about the experience and to keep a log because each weekly exercise required skills developed the previous week.

Exercises

The following exercises are intended to be conducted in an appropriately equipped laboratory. As always, there are essential safety precautions to be observed whenever chemicals, biologicals, or electrical instruments are involved.

A list of equipment is included with the references. Though not specifically mentioned, it is assumed that support equipment and supplies will be available, including laboratory glassware, refrigerated storage for supplies, a distilled or deionized water supply, a sterile hood or work area, and an incubator.

The following are brief descriptions of the exercises as first implemented in the Medical Laboratory Technology program:

Basic Laboratory Skills

Students began by performing serial dilutions by micropipetting an indicator dye in a log sequence of 1:1–3–10–30–100–300–1000–3000–10,000–30,000–100,000–300,000–1,000,000. Once this was accomplished, students set up and calibrated an ultraviolet and visible spectrophotometer and assayed the absorbance of each dilution after empirically finding the wavelength of maximum absorption. A graphed log-linear plot was assembled and the usable range of measurement for the dye as observed was noted. Any errors in pipetting were made apparent by the plot, and methods of corrective action were suggested by the students themselves.

Solutions, pH Measurement, and Protein Concentration Measurement

This exercise involved comparison assays of three different protein assays on unknown solutions of proteins. The assays compared were the Lowery, coumassie blue, and ultraviolet absorbance (280 nm). Students worked in groups of two and were charged with delegating the order and priority of tasks including solution preparations, spectrophotometer calibrations, and pipetting. A final graph of 10 standards versus unknowns was submitted along with calculations based on the ratios.

Enzyme Assays

Enzyme assays made up the bulk of the scheduled laboratories for the clinical chemistry students. Students attended lectures on the theory of measurement and assay techniques and then conducted the following assays: linked, chromophore, and direct indicating and indirect indicating assays (Calbreth, 1992). Enzymes assayed include lactate dehydrogenase, transaminases, amylase, creatine kinase, cholinesterase, and alkaline and acid phosphatases.

Electrophoretic Techniques

Electrophoresis is a specialty area of clinical chemistry and has direct application to biomedical research, including genetic research. Consequently, it was the focus of three laboratory sessions as follows:

- ♦ Serum protein analysis: separation of the five principle diagnostic protein bands in normal and disease states. Abnormal samples (myeloid leukemia, multiple myeloma, and multiple sclerosis) were obtained for comparison (Raphael, 1993).
- ♦ Cardiac isoenzymes: creatine kinase and lactate dehydrogenase. As in the laboratory session above, abnormal serum samples were obtained for comparison.
- ♦ Hemoglobin variants and thalassemias: hemoglobins. Adult hemoglobins were analyzed for normal as well as inherited abnormal forms. Samples were obtained, including sickle-cell and fetal preparations.

Evaluation and Further Development of Laboratories

After observing students using these exercises in the laboratory, faculty members concluded that these laboratory exercises could be expanded to include molecular biology exercises incorporating electrophoresis. These exercises would be applicable to the diagnostic and forensic areas of medical laboratory technology as well as to the macromolecules and genetics areas of a general biology laboratory.

With funding from the Darton College Foundation, the medical laboratory was expanded to include DNA and RNA electrophoretic analysis, and many of these same laboratory exercises were incorporated into the general biology laboratory in the summer of 1995. New research-grade electrophoretic equipment and power supplies were purchased. This allowed the use of a greater variety of gel electrophoresis techniques in the general biology laboratory. Laboratory assignments included an overview of proteins and nucleic acids (DNA and RNA). After an introductory DNA laboratory designed to bring students up to the skill level needed for these techniques (an alkaline and an acid phosphatase enzyme assay), the new laboratory exercises were implemented.

Expanded Laboratory Assignments in Medical Laboratory Technology and General Biology

Proteins as Macromolecules

Native protein electrophoresis: separation of cytochrome C, hemoglobin, albumin, and myoglobin under native, nonreducing conditions in an agarose gel. Students worked in groups of four during a three-hour lab period. All equipment and solutions were prepared from packaged reagents. Subsequent activities included staining, destaining, and creating a graph of the mobility profiles.

Consequences of Genetic Variation on Protein Structure/Function

Separation of sickle-cell hemoglobin from normal non-sickle-cell hemoglobin: Students again worked in groups of four. Included in this assignment was a report outlining the applications to other genetic traits.

DNA as a Macromolecule

Analysis of predigested DNA fragments to determine the length relationship to electrophoretic mobility in a horizontal agarose gel: By this time, students were proficient at the manipulations and protocol of setting up and running gels and worked in groups of three or four with minimal supervision. After successfully completing the introductory DNA exercise, students carried out restriction mapping of lambda phage DNA using the endonucleases Eco R1 and Bam H1. Using a known map of the complete genome of lambda phage, students were responsible for ascertaining the gene complement and base pair size of each resultant fragment.

Manipulation of DNA

Plasmids as vectors: Students in groups of four to six prepared host (*E. coli*) cells in advance and rendered them competent for transformation by a prepared plasmid (pUC18) containing a polylinker and a gene encoding ampicillin resistance. The follow-up analysis required students to isolate colonies of *E. coli* expressing ampicillin resistance.

Conclusion

Many texts used in general biology, molecular biology, genetics, and genetic engineering focus on theory (Wallace, 1991). In the corresponding texts for clinical chemistry, applications are emphasized. Students need more exposure, however, to applied techniques in these

fields. Combining resources and faculty input in the disciplines of medical laboratory technology (clinical chemistry) and biology (biochemistry and molecular biology) has enriched the graduates of those programs. With these acquired skills and exposure to applications, it is possible for community college graduates to undertake employment or further study in the field of molecular genetics and, in fact, contribute to the genetics revolution.

Equipment and Technology Required

- ◆ Electrophoresis apparatus and power supply (Beckman Instruments, Paragon Electrophoresis Systems, Clinical Instruments Division, 200 South Kraemer, Brea, CA 92621, and Modern Biology, Inc., 111 North 500 West, West Lafayette, IN 47906)
- ◆ Reagents for electrophoresis and enzyme assay (Sigma Chemical Company, P.O. Box 14508, St. Louis, MO 63178, and Beckman and Modern Biology, Inc.)
- ◆ Precision pipetting equipment
- ◆ Laboratory spectrophotometer and accessories (Fisher Scientific, 485 South Frontage Road, Burr Ridge, IL 60521).

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20

A DNA Fingerprinting Exercise for Any Type of Class

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Abstract: An interactive learning exercise, adaptable to a wide variety of subjects and types of courses, has been designed to teach students about DNA fingerprinting. The focus is on basic principles so that this subject may be addressed by instructors with different backgrounds. Students use strips of paper with DNA sequences to identify a potential murderer by determining the probability of finding a specific DNA pattern. BB.

Relevant disciplines: genetics, biotechnology, statistics, introductory biology

Introduction

Hands-on laboratory exercises are excellent teaching tools because they have the potential to reach students with all types of learning styles. Unfortunately, the large monetary investment required to obtain supplies and equipment and to train instructors prevents many schools from providing hands-on learning experiences with DNA technology. Students in nonlaboratory courses are even less likely to gain an appreciation for the types of information that can be obtained from DNA analysis. Courses such as mathematics, statistics, community education, and nonmajors' science courses can include DNA analysis as a topic if this information is presented well in the absence of a lab. Therefore, low-cost alternatives to traditional laboratory exercises are desirable in order to convey principles of DNA technology to a wider variety of students. The importance of understanding DNA analysis is clear; as the use of DNA information becomes pervasive in society, everyone from a jury member to an individual applying for health insurance will have to make decisions about information derived from DNA analysis.

At Seattle Central Community College, students using evidence obtained from the scene of a crime and a DNA fingerprinting technique determine the identity of a criminal. This learning exercise can be used in either a laboratory or a lecture-style course and can accommodate almost any budget, as the cost is limited to providing strips of paper and scissors. Although this exercise was originally designed as part of a genetics course for biotechnology majors, it also has been used successfully for nonscience majors.

Applications of DNA Analysis

DNA analysis has broad applications. Doctors now use genetic tests to detect specific types of inherited disease such as Huntington's disease or cystic fibrosis. Tests have also been developed to identify an inherited predisposition to certain types of breast cancer and Alzheimer's disease. As more is learned about the information stored in genetic material, DNA tests may be used more widely in preventive medicine to help individuals avoid specific foods or certain environmental conditions. However, DNA analysis is no longer confined to genetic and medical research. Most students are aware that forensic science relies heavily on the ability of DNA to identify the source of biological substances and determine who is

most likely to have committed a crime. This ability to identify an individual is enhanced by the variety of substances that contain DNA, including blood, semen, saliva, hair, urine, bone, teeth, feces, and tissues. In a highly publicized case, the FBI announced that it was able to match DNA samples from letters mailed to relatives by Theodore Kaczynski with DNA obtained from stamps on letters mailed by the Unabomber.

Identification of specimens using DNA has had other benefits. In one-third of the cases where this technique has been used, DNA analysis has been able to exonerate people wrongly accused of crimes. Prisoners wrongly accused of rape or murder have been freed on the basis of DNA evidence. DNA analysis is now a common tool for establishing paternity, and it has been called on to identify remains after tragedies such as airline accidents and the inferno at the Branch Davidian complex in Waco, Texas. Anthropologists are using DNA analysis to study the migration of human beings across the oceans, and historians employ these techniques to identify genetic disease in famous deceased individuals. The variation of DNA sequences between species and individuals also has been useful for wildlife biologists attempting to track endangered species.

Features of DNA That Are Important for Analysis

DNA is composed of four different chemical building blocks called bases. Complementary base pairs are found along the entire length of the DNA duplex. The complementary nature of the two strands provides a basis for copying genetic information and for passing this information on to offspring.

Information is stored in DNA in the sequence of bases just as information can be stored in a book in the sequence of letters. The total amount of DNA in one cell is known as the genome.

Techniques Used for DNA Fingerprinting

DNA fingerprinting analysis relies on a combination of several different techniques. DNA must be isolated from different types of samples and digested with enzymes, and DNA fragments must be separated by size using agarose gel electrophoresis. A replica of the gel, containing the DNA fragments, is created by treating the gel with chemicals that cause the DNA to denature (separate into single strands) and then transferring the DNA to a

filter. Specific pieces of DNA are detected on the filter by a process called hybridization. Hybridization capitalizes on the complementary nature of two DNA strands. A piece of DNA called a probe is labeled to allow for detection, boiled—causing it to become single-stranded—and added to the filter. The probe DNA detects specific DNA sequences on the filter because it is able to bind only to fragments that contain the sequence of bases complementary to the probe.

In order to fit this exercise into a lecture period, a detailed discussion of the techniques used for sample isolation, blotting, and hybridization has been omitted. While these steps are important for an in-depth understanding of DNA analysis, a sufficient understanding of the ability of DNA fingerprinting to identify an individual can be based on a few fundamental concepts. These are: (1) DNA is cut into different-size pieces by enzymes that recognize specific DNA sequences, (2) the sizes of these fragments can be measured and will vary among individuals, (3) each pattern of fragments occurs with a certain frequency in a population, and (4) we can calculate the likelihood of finding a specific combination of patterns within a population.

DNA Fingerprinting with Restriction Fragment Length Polymorphisms

Two alternative methods can be employed for DNA fingerprinting: restriction fragment length polymorphism (RFLP) analysis and polymerase chain reaction (PCR). Both methods are able to identify patterns of specific DNA sequences from a wide variety of biological samples. Samples that are in good condition and contain enough DNA can be analyzed by looking for specific RFLPs that occur in highly variable, noncoding parts of the genome. RFLPs are patterns of DNA fragments of different lengths created when restriction enzymes cut DNA at specific sequences. The fragments are said to be polymorphic because the sizes can vary between individuals.

Variable Number of Tandem Repeats (VNTRs)

VNTRs are a type of DNA sequence often used for forensic analysis. VNTRs can vary in length between 1,000 and 20,000 bases; within a VNTR there are base sequences of a shorter length (15 to 75 bases) that are repeated, with the number of repeat units varying between individuals.

If a volume from a set of encyclopedias is used as an analogy for the DNA in one chromosome, a VNTR could be thought of as a paragraph. This paragraph would contain the same sentence repeated over and over again. Every edition of that volume would contain this same paragraph on the same page, but the paragraph would be a different length in each book. The length would vary from edition to edition because the sentence would be repeated a different number of times each time the volume was printed.

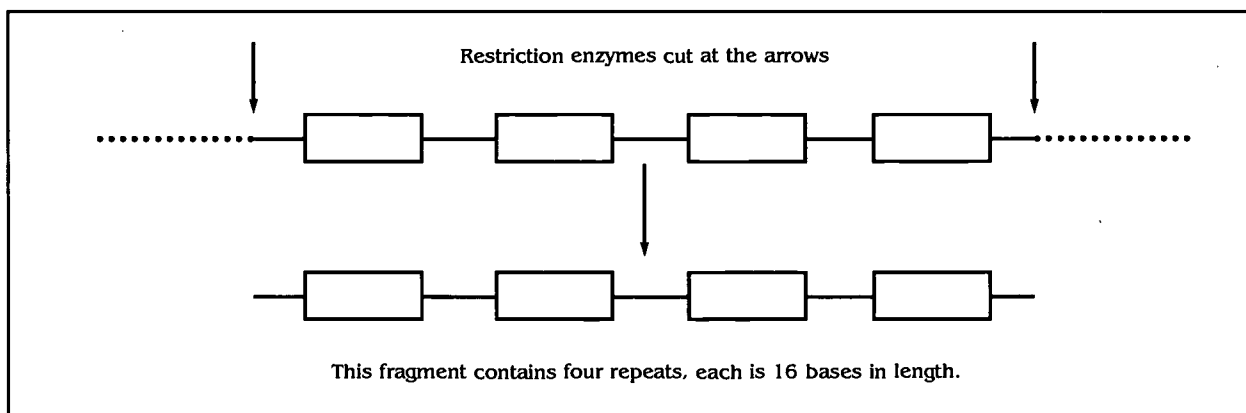
An example of a VNTR found in humans is a chromosomal site known as D1S80. The size of the repeating sequence in D1S80 is 16 base pairs long. The D1S80 sequence is located on chromosome 1 and is usually repeated between 14 and 40 times. Restriction enzymes are used to cut DNA on both sides of the repeating sequence, generating a fragment whose

A Comparison of the RFLP and PCR Techniques

PCR is a far more sensitive technique than RFLP analysis because the reaction requires only a tiny amount of DNA. RFLP analysis requires at least 50 nanograms of DNA where only two nanograms (the amount of DNA in 400 cells) is needed for PCR. PCR is also faster; this technique can be performed in two to three days rather than the four to eight weeks required for RFLP analysis.

The advantage of the RFLP method is that regions of the genome are examined that show more variation than those typically analyzed by PCR. A particular RFLP fingerprint might occur in one out of every 100,000 to 100 million people, while an individual PCR fingerprint would occur more frequently, on the order of one per few thousand people.

Figure 20.1 Use of the PCR for DNA Fingerprinting



length is determined by the number of repeats, as shown in Figure 20.1.

Often, DNA samples obtained from crime scenes are too small in quantity or too degraded by sunlight or high temperature to be analyzed by the RFLP method. If such is the case, these samples are subjected to a different fingerprinting technique known as PCR. PCR is a valuable technique because it provides a method for producing millions of copies of small regions of DNA. Again, in comparing a chromosome to a book, PCR could be thought of as a molecular photocopy machine that would produce several million copies of a single paragraph.

DNA Fingerprinting in Class

This exercise focuses on RFLP analysis using strips of paper with sequences of letters to represent segments of DNA. Students identify specific sequences (restriction sites) on each paper strip and cut (or tear) the paper wherever that restriction site occurs. Instead of using agarose gel electrophoresis, they determine the size of each DNA fragment by counting the letters. The sequences of DNA used for this exercise are much shorter than the DNA fragments analyzed in real-life laboratories. This change has been made in order to minimize the time spent counting letters.

After the students find all of the restriction sites and count the letters in each fragment, the data are pooled

and used to estimate the frequency of different restriction fragment patterns in a sample population. These results are used to determine if a blood sample from a crime scene contained DNA from the victim or any one of three suspects. The class also calculates the probability of any other person having a DNA fingerprint identical to the suspect.

Description of the Crime

To make the exercise more interesting, crime scenarios can be borrowed from the newspaper or any mystery novel. Many recent high-profile cases would be appropriate choices and are matters of public record. In this exercise the identities of the victim and the suspects are borrowed from the Parker Brothers game, *Clue*. Miss Scarlet's body was found at midnight in Mrs. Peacock's library by the maid (Mrs. White), apparently the victim of a murderer. A candlestick lay near the body in a pool of blood. The suspects include Mrs. Peacock, Professor Plum, and Mrs. White. Mrs. Peacock, a wealthy middle-aged heiress, was known to hate Miss Scarlet for stealing the attentions of her ex-suitor, Colonel Mustard. Professor Plum, the noted con artist, may have had reason to silence Miss Scarlet: Only she knew his true identity. Perhaps even sweet Mrs. White had her own reasons. She despised Miss Scarlet and blamed Miss Scarlet for the death of her only son.

Pieces of paper with DNA sequences (one strand only) are handed out to all members of the class (examples are given in Figure 20.2). Each sample is labeled to indicate the source. A minimum number of DNA sequences would be two strips of paper for each of the suspects, four for the crime scene, two for the victim, and at least 10 for the general population. The size of the general population sample can be increased so that all students get their own DNA sequences.

Figure 20.2 DNA Fragments

5' GAATTC CATACGAGTCCC 3'

Mrs. Peacock

5' GAATTC CATACGAGTCCC 3'

General population

5' GGAATTC CATACGAGTCCC 3'

Crime scene

5' GGAATTC CATACGAGTCCC 3'

Mrs. White

5' GGAATTC CATACGAGTCCC 3'

General population

5' GGAATTC CATACGAGTCCC 3'

Professor Plum

5' GGAATTC CATACGAGTCCC 3'

General population

5' GGGGAATTATACGGAATTC 3'

Professor Plum

5' GGGGAATTATACGGAATTC 3'

General population

5' GGGATTC CATACGAGTCCC 3'

Miss Scarlet

5' GGGATTC CATACGAGTCCC 3'

Crime scene

5' GGGATTC CATACGAGTCCC 3'

General population

5' GGGGGAATTCACGAGAATTC 3'

Miss Scarlet

5' GGGGGAATTCACGAGAATTC 3'

Crime scene

5' GGGGGAATTCACGAGAATTC 3'

General population

5' GGGATTC CATACGAGTCCC 3'

Crime scene

5' GGGATTC CATACGAGTCCC 3'

Mrs. White

5' GGGATTC CATACGAGTCCC 3'

Mrs. Peacock

5' GGGATTC CATACGAGTCCC 3'

The crime scene is described to the students, and they are told that the class will work together to identify the potential murderer. A picture of a double-stranded DNA molecule is shown to the class. At this point it can be helpful to ask the class how many different letters they

see and explain that each letter of the four letters in their sequence represents a specific chemical structure called a base. Although DNA has two strands, they have only been given the sequence of one strand because in DNA, the sequence of one strand determines the sequence of the other. As an additional exercise, the students can determine the sequence of the complementary strand. Students are then told that special proteins called restriction enzymes are able to find specific base sequences and cut the DNA wherever that sequence occurs.

Digestion of the DNA

In this class, the students will replace the restriction enzymes. They are told to look for the following sequence: 5' GAATTC 3' (the 5' and 3' numbers show the orientation of the DNA sequence); when they find this sequence, they are to act like the restriction enzyme, EcoRI, and cut the sequence after the G. Then they count the number of letters (bases) in each "fragment." Some DNA sequences have one site for EcoRI; some have multiple sites. Students need to cut this sequence every time it occurs. They could also draw a line after the G with a pen and count the number of bases on each side of the line or lines.

Collecting and Analyzing the Data

After students have counted the number of bases in each EcoRI fragment, the results are tallied and written in a table on the board (or overhead) as shown below. Students are asked what conclusions can be drawn from the data at this point. They should notice that the DNA fragments can be different sizes and that the sizes can vary between individuals. A picture of a gel is also shown to illustrate how these fragments might look when separated by agarose gel electrophoresis. The movement of DNA fragments through agarose gels is inversely proportional to the log of their molecular weight. In other words, smaller fragments move faster than larger fragments, and it is easier to distinguish differences in size between smaller fragments than between larger fragments. It might be helpful to point out, too, that real-life gels have less resolving power than the gel in the picture and that it would be impossible to distinguish between DNA fragments that differ in size by only one base using an agarose gel.

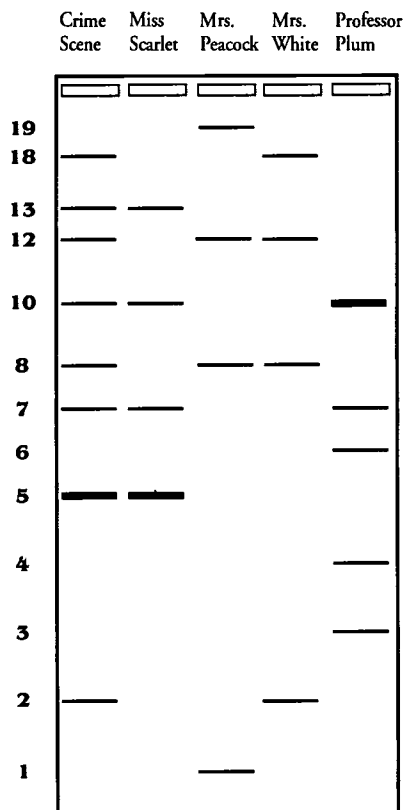
Table 20.1 Analysis of Blood Samples

IDENTITY OF SAMPLES	FRAGMENT SIZES	NUMBER OF STUDENTS WITH THIS PATTERN	PROBABILITY OF SEEING EACH PATTERN
Crime scene sample	13, 7 10, 5, 5 2, 18 8, 12	1 1 1 1	
Mrs. White	2, 18 8, 12	1 1	3/30 5/30
General population	13, 7	2	2/30
(Sample size = 30)	10, 5, 5	10	10/30
	2, 18	3	3/30
	8, 12	5	5/30
	6, 4, 10	4	4/30
	3, 10, 7	5	5/30
	1, 19	1	1/30

Analysis of the Pattern of Fragments in the Gel

The picture of a gel (Figure 20.3) shows that the differently sized DNA fragments create visual patterns. Using the gel, the students can begin to solve the mystery by trying to identify the source of the blood found at the crime scene. In this case, the pattern of restriction fragments from blood found at the crime scene is compared with the patterns from the potential suspects and the victim. Table 20.1 and the gel (Figure 20.3) show that all of the DNA fragments (13, 10, 7, 5) found in Miss Scarlet's blood are present in the sample from crime scene. The two five-letter fragments show students what might happen when two DNA fragments are the same or close to the same size. Professor Plum's DNA fragments don't match any of the fragments from the crime scene DNA, so he can be ruled out as a suspect. Next, the pattern from Mrs. Peacock's blood contains two fragments (12 and 8) that are the same size as DNA fragments in those from the crime scene. However, the other fragments seen in her blood (19 and 1) are missing from the crime scene sample, allowing her to be ruled out as well. All of the fragments seen in Mrs. White's fingerprint can be found in the crime scene sample, making her the most likely suspect.

Figure 20.3 Pattern of Fragments in Gel



Students are asked to give explanations for the presence of the 12- and eight-letter fragments in samples from both Mrs. Peacock and Mrs. White. This pattern could arise if the two women are related or if this pattern were common in the population.

Statistical Analysis

The probability of finding Mrs. White's DNA fingerprint in the general population is then calculated. The probability of finding any one pattern is equal to the number of times that a specific pattern is found divided by the sample size. The sample size will be determined by the number of students holding the general population sequences. This will vary for every class, so it is best to draw a table like Table 20.1 on an overhead transparency and fill in the numbers during the exercise.

The probability of finding a combination of two restriction patterns is determined by multiplying the probability of finding each pattern. The probability of finding a pattern that matches Mrs. White's is $(3/30)(5/30) = 1/60$. One person in a group of 60 people might have the same fingerprint as Mrs. White. Of course the calculation might be a bit misleading because a random group of 60 people wouldn't have been in Mrs. Peacock's living room in the middle of the night. It is important to remember that the circumstances surrounding a crime are important.

Analysis of Multiple Sites in the Genome

The results of RFLP analysis become more convincing with data from additional regions of the genome. To illustrate why this is true, data from other portions of the genome can be included in this exercise. For this analysis, it is important that the regions of DNA tested in this process must not be linked. If two sites are linked, then they would tend to occur together and the probability calculations would be invalid. Unlinked sites are often located on separate chromosomes. A typical analysis in a criminal case might require the examination of as many as 10 different sites.

To save time, students are either given the frequencies for each restriction pattern or asked to determine these numbers outside of class. The probability of obtaining another matching pattern of fragments is then determined for the combination of all the RFLP patterns tested. In the case of Mrs. White, we might find that the restriction patterns for DNA regions B, C, D, and E

found in her genome occur in the general population with the following frequencies: 1/20, 1/50, 1/100, 1/200. The probability of having the same set of restriction patterns as Mrs. White at regions A, B, C, D, and E would equal $(1/60)(1/20)(1/100)(1/50)(1/40) = 1$ out of 2.4×10^8 people. As the population of the United States is close to 2.6×10^8 , this means that only one person in the United States would be likely to have a restriction pattern identical to Mrs. White's.

Sources of Error in DNA Analysis

At the end of the exercise, drawbacks or potential sources of errors in DNA fingerprinting are discussed. Students are reminded that DNA fingerprinting can identify the most likely source of DNA in a sample, but this technique cannot determine how that DNA got into a sample. Proper sample handling and chain-of-custody procedures are important aspects in proving a criminal case. Perhaps Professor Plum obtained a sample of Mrs. White's blood and poured it over the candlestick after killing Miss Scarlet.

At one time, it was thought to be important that the allele frequencies represented the ethnic group of the suspect. If a restriction pattern were to occur more frequently in a population, the probability of finding that pattern would be much higher. Data obtained since that time have revealed that few differences exist between different ethnic groups.

The FBI has assembled a national database of DNA fingerprints, and this information has been used to track sex offenders and identify serial killers. The FBI has also created a computer program for determining the sizes of the DNA fragments separated by agarose gel electrophoresis. This program is used to determine the sizes of DNA fragments in a consistent manner and minimize human error. A detailed description of DNA fingerprinting in forensics and paternity testing can be found in the book *DNA in the Courtroom* (Coleman and Swenson, 1994).

As noted earlier, this paper has omitted any discussion of DNA hybridization and in-depth descriptions of many of the techniques used in producing a DNA fingerprint. In this case, omitting some of the technical details makes the subject easier to teach in nongenetics courses such as mathematics and statistics. Through this exercise, students at all levels gain an understanding of the power of DNA fingerprinting as well as the drawbacks.

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PART III

Biotechnology Programs

21

An Interdisciplinary Approach to Genetics in a Biotechnology Program

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Abstract: Middlesex Community College has developed a certificate and degree curriculum for an interdisciplinary biotechnology program using a team approach in which faculty participants meet to discuss and develop connections between the courses.¹ The three courses that are central to the biotechnology program are Methods of Biotechnology, Economics and Management in High-Tech Industry, and Biomedical Ethics. The approach simulates industrial practice and has proved effective in providing students with the skills and knowledge they need for employment.

Relevant disciplines: biotechnology, ethics

The Biotechnology Program

Middlesex Community College began offering a biotechnology certificate in 1990 in response to an industry request for programs to produce technicians. Local industry participated in developing the curriculum and continues to provide instructors for several of the courses as well as feedback and evaluation based on their experiences with the graduates. In six years, almost 100 percent of the 141 certificate graduates were placed in area biotechnology companies.

In order to qualify for the program, applicants must place in college-level English and Algebra II. No previous science background is required. Prospective students are selected through an interview process by the program coordinator and a member of the college admissions staff. The certificate program has a general education component as well as courses more closely related to biotechnology: Methods of Biotechnology, Quality Control and Good Manufacturing Practices, and Microbiology. The biology, mathematics, and chemistry courses that certificate students take have a strong biotechnology emphasis. At the completion of the program, students are placed in a work-based internship.

Recently, an associate degree program built on the certificate courses was initiated. All of the certificate course credits apply to the associate degree. While the certificate emphasizes preparation for employment, the subsequent associate degree courses help enable transfer to baccalaureate institutions. The curriculum adds more advanced science and biotechnology courses including Biochemistry, Immunology, Molecular Biology, Advanced Techniques of Biotechnology, and Special Topics in Biotechnology. To meet the general education course requirements, the faculty team developed two new courses with applications to technologies, Biomedical Ethics and Economics and Management in High-Tech Industry.

The NSF-ATE Project

A grant from the National Science Foundation has facilitated the development of curriculum at the high school and associate degree level. Objectives of this effort are teacher training, program implementation, articulation between educational levels, dissemination, and minority

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recruitment. The major partners are Minuteman Science and Technology High School (Lexington, Mass.), with its four-year Biotechnology Academy program for high school students, and Worcester Polytechnic Institute (Worcester, Mass.).

Curriculum Development at Middlesex Community College

Curriculum development has been a cooperative effort in which faculty from all the disciplines included in the program meet regularly to discuss common issues and develop connections between the disciplines. These meetings are augmented by summer workshops in which faculty learn about new pedagogies. Much of the curriculum writing is done with participating faculty consultation and collaboration. The curriculum is written in self-contained modules so that faculty from other institutions can borrow what they find useful without having to commit to using an entire course. As the modules are piloted, and assessed, changes are made. Curriculum is then reviewed at other schools and by industry personnel. All of the materials are regarded as “works in progress.”

Interdisciplinary connections between the courses are emphasized and represented by concept maps for each module. The following are descriptions of three courses in this associate degree program, along with their connections to genetics: Methods of Biotechnology, Biomedical Ethics, and Economics and Management in High-Tech Industry.

Methods of Biotechnology

Course Overview

The Methods in Biotechnology course is taught after students have taken courses in English composition, mathematics, chemistry, and biology. It is a part of both the certificate and associate degree programs and it is taken simultaneously with the course Quality Control and Good Manufacturing Practices (GMP) so that students can apply the principles of GMP to the methods course.

The goals of the course are to provide entry-level biotechnology skills, to inform students of ethical issues, and to provide them with a scientific understanding that will enable them to continue in subsequent study, and help them learn behaviors required in industry such as responsibility, following standard operating procedures (SOPs), and teamwork. After students have taken the

methods course and the GMP course, they are eligible for a guided work experience. Topics covered include regulation and biotechnology, media preparation, cell growth and maintenance, freezing and thawing cells, chromosome preparation, monoclonal antibodies, electrophoresis, western blot transfer, diagnostic procedures, and ELISA (enzyme-linked immunosorbent assay). The course is cumulative in that each topic leads to the next topic. Students are constantly using techniques learned in previous weeks, so previously learned skills are reinforced.

Industry Simulation and Student Evaluation

The course is designed to simulate industry in several ways so that students get an idea of the work skills that will be expected of them when they begin employment. Students follow SOPs, make decisions about what procedure is needed in their task, work in teams, follow proper gowning and aseptic techniques, and are evaluated on behaviors required in industry. The decision-making process involves maintaining the viability of cells.

Another way in which the course simulates the workplace is in the conduct of the labs. Labs usually require more than one period and extend beyond the scheduled time. Students can leave only at the end of a lab period when the cells are in a sustainable condition. They also monitor the cells between labs. The students keep a lab notebook, which cannot leave the laboratory. They often have several projects in progress. At the completion of a project, the student submits a final lab report similar to that required in industry to communicate the results to a supervisor or to someone in another department. Students are evaluated on skills and attributes required in industry including lab skills, aseptic technique, professional behavior, teamwork, and initiative.

Discussions of Legal and Ethical Issues

Throughout the course, students discuss the legal and societal implications of techniques as they are introduced to them. Examples of topics discussed are DNA analysis (fingerprinting, paternity determination, diagnosis of inherited diseases), use of genetic information (confidentiality, effect on employment, insurance), analysis of human karyotype (prevention, diagnosis, inheritance of genetic diseases), and prenatal diagnosis of genetic disorders (procedures, use, and misuse).

Introduction to Biomedical Ethics

Course Overview

The Introduction to Biomedical Ethics course helps students develop a critical awareness of the ethical issues they will deal with on the job and provides students with a framework for making informed ethical decisions. Typically, the course attracts a combination of students from the biotechnology and nursing programs, and other allied health programs, as well as a mixture of interested students from the liberal arts and sciences.

The course is a combination of elements commonly found in bioethics and medical ethics courses with emphasis on the ethical theories (e.g., Utilitarianism and Kantianism) and principles (e.g., respect for autonomy) and what might be called workplace ethics.

Other distinctive features of the course include:

- ♦ Deliberate strategies designed to convey the interdisciplinary nature of knowledge
- ♦ Emphasis on course goals and objectives
- ♦ A combination of methods to evaluate student performance (examinations, journal writing, research writing)
- ♦ Use of case studies to concretely illustrate key ideas and principles
- ♦ Regular use of assessment instruments throughout the course to measure the effectiveness of each of the learning activities

Course Outline

Some of the topics routinely taught include ethical principles, case studies, theories and dilemmas, rights of patients and subjects, responsibilities of professionals, management of medical information, reproductive decision making, and decisions about the end of life. Human and animal experimentation is discussed as well as eugenics, the Human Genome Project and genetic testing, human gene therapy, and justice in health care.

Pedagogical Techniques in the Course

In-class writing is regularly used to help students express their more immediate reactions to ideas in the course. One result of this is that students who might normally speak very little gain a voice and are more likely to speak.

Case studies are used, usually in conjunction with group work in class. Students like case studies because they tell a story that seems to be particularly relevant,

real, and concrete. The challenge is in getting the students to identify the relevant principles and apply them to the situation revealed in the case.

Students are asked to assess the program and its components at least six times during the semester. The information gathered from the assessments is addressed immediately with students in class. Students usually use assessment to make constructive comments and appreciate the opportunity to become active participants in the learning process.

Economics and Management in High-Tech Industry

Course Overview

This course is designed to prepare students to understand and interpret the business environment in which they will be employed so that they can make good decisions in their own and their company's best interests. The goal of the course is to define the economics that affect the business climate and explain the organizational structures through which scientific and technological discoveries and innovations are financed, developed, manufactured, priced, promoted, and distributed. The course is generally taken after or while students are participating in internship experiences or have been employed in the industry. Most of the students enter the course with a strong technological background but little or no understanding of or interest in how business structures work.

The course is interdisciplinary and is team-taught by an economics instructor and a management instructor who together created the course and attended every class. The course combines traditional principles of economics and business as a framework for understanding today's rapidly changing corporations and businesses.

Course topics include our economic system, laws of costs and production, economics of the firm, current microeconomics issues, business ethics and social responsibility, business organizations, marketing management, human resource management, and international businesses.

Pedagogical Techniques

Case studies and reports on articles chosen by the students, and an interview with an industry manager, are all used to supplement the text and lecture. Class discussions are enriched through students' personal experiences in their work or internships.

The students choose articles from appropriate cur-

rent magazines or newspapers and submit a written report on each in which they comment on their interest in the company or subject, the relationship of the article to the text and their individual experiences, and the usefulness of the assignment.

Students make oral reports in a seminar format. Instructors comment that this is the most useful part of the course because students see connections between the different industries. For example, one student reported on the Human Genome Project and another on advances in the hardware and software industries. The class made the connection that it was the hardware and software advances that made the Human Genome Project possible.

Case Studies

Case studies are taken from the textbook and periodicals. For example, an article, "The Gene Kings" (*Business Week*, May 8, 1995), focused on the different reactions in the scientific and business communities to the technology of rapidly finding and sequencing genes. The study was used to illustrate steps in new product development, the process of creating and affiliating companies, leadership traits, business ethics, and the effect of governmental regulation. Other case studies included the response of Johnson and Johnson to the Tylenol scare, which illustrated crisis management and a corporate code of ethics.

Interview with a Manager

At the end of the semester, students arrange, conduct, and report on an interview with a manager in their chosen field. The goals of the assignment are to give the students an idea of what skills are required of a manager, get an overall sense of the operation of a company, and to learn what the job of manager is like.

Students find that many of the managers were formerly scientists and technicians. This shows students how the skills and knowledge gained from the course can enhance their careers.

Student Portfolio Assessment Process

Throughout the program students collect material for a portfolio to document their growth—in other words, how their thinking and values have evolved. This also gives the students an opportunity to do some self-evaluation, provides more exposure to scientific literature, and provides them with an additional mechanism to talk with program faculty about the quality of the program and their progress in it. As students progress

through the program, the readings are made progressively more difficult.

Students are asked to retain their work throughout the semester and to choose items for the portfolio. In addition, students are asked to write a one-page paper in answer to a question, such as, What do you think about experimentation with human cells? Students meet with faculty advisers to turn in their portfolios and discuss their progress in the program and their feelings about the program.

Summary

Middlesex Community College has developed a biotechnology program that provides biotechnology applications across the curriculum, develops connections between the courses, and prepares students for occupations in the industry. The success of the program is demonstrated by student response and assessment and the nearly perfect placement rate of our students.

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22

Instilling Job Literacy for Current and Upcoming Biotechnology Occupations

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Abstract: This paper describes a philosophy of preparing students for success in current and upcoming careers in biotechnology and advocates the integration of universal job-related skills into the two-year college biotechnology curriculum. A strategy for modeling the work environment in the classroom is discussed. The strategy includes methods of evaluating the students and the curriculum. The workforce skills, as defined by various sources, are listed and categorized in behavioral and technical skills components.

Relevant discipline: biotechnology

Introduction

A major challenge facing community colleges is meeting the constantly changing demands of high-technology occupations. Biotechnology, particularly, has been an area of great concern. It is becoming a vocation of its own and is expanding into many occupational areas that at one time were classified as low-tech and demanded employees with few technical skills and little scientific knowledge. Occupations involving agriculture, chemical production, food manufacturing, law, and textiles are showing changing job skill needs as a result of biotechnological advances. Even the small, privately owned farm now necessitates employees with skills in artificial insemination of livestock, handling genetically altered crops, and applying biological pest control to crops and livestock. Instead of treating clothes chemically and mechanically to color, soften, and finish the fabric, the textile industries are using biologically active agents for these processes, and other manufacturing areas are making similar use of biotechnology. Large food producers have replaced traditional chemical testing with biological assays and animal cell culture testing to ensure food quality and safety.

Several community and technical colleges in North America are developing new programs and expanding current biology programs to address the needs of the growing biotechnology industry. A common feature of most of the programs is the intensive teaching of technical skills needed to perform the complicated laboratory tests and field activities that constitute much of biotechnology. Usually, the skills to be taught were chosen with assistance from an advisory board composed predominantly of the immediate industries being served by the program. Community colleges had to address the earmarked skills in the academic preparation of their students. Lloyd V. Hackley, president of the North Carolina Community College System, commented on this challenge in the *Community College Times* (1996). He wrote that community colleges must teach skills in a manner that provides the workforce with properly prepared individuals without compromising the success of students.

Designing a curriculum that inculcates the skills needed for occupational success is not a simple task. A list of skills cannot be determined solely by either employers in that occupation or by educators. Employers generally focus on the specific nature of certain jobs within an occupational area. Educators tend to focus on the student as a continually developing individual. Their emphasis is on teaching students to understand why something needs

to be done. Today, employers are encouraging colleges to focus on the universal skills that produce a workforce capable of performing general technical tasks and willing to do continuous on-the-job training.

Kingwood College went through a restructuring of its Biotechnology Program so it would better meet the growing needs of the biotechnology industries. It broadened its goal of training students primarily for academic laboratory positions. The curriculum changes permitted students to acquire the skills needed for biotechnology work in agriculture, environmental testing facilities, forensic laboratories and industry, and to be successful in other science career paths. These curriculum changes required an analysis of the job literacy skills community college graduates needed to succeed in a variety of biotechnology careers.

Defining Job Literacy Skills

Job literacy can be defined as the knowledge and skills needed to perform satisfactorily all aspects of a particular job. All jobs require two sets of skills. One set is needed to perform the technical aspects of a job, the required hands-on components of job-related tasks. For example, biotechnology skills include conducting laboratory procedures and safely handling biological materials. The other set of skills includes the behaviors needed to perform within the social climate of the occupation. Critical thinking, organizational skills, and responsibility are three of the behavioral skills needed to adapt to the etiquette of a job and properly conduct all job components. Unlike many technical skills, behavioral skills are universal to other jobs and other social settings.

Job skills can be classified into several broad categories that encompass both the technical and the behavioral skills. The list of skills provided below is a compilation of job literacy skills recognized by industry leaders, vocational educators, and the Secretary's Commission on Achieving Necessary Skills (SCANS, 1991). Also included are workforce skills expected by biotechnology employers in the Houston, Texas, area.

Basic Intellectual Skills

- ◆ Reading for accurate interpretation
- ◆ Writing for clarity and universality
- ◆ Listening for accurate and thorough communication
- ◆ Mathematical calculating for solving applied problems
- ◆ Content knowledge attainment for gathering accurate facts

Higher Cognitive Skills

- ◆ Decision making to solve immediate and long-term problems
- ◆ Creative and critical thinking to produce new problem-solving strategies
- ◆ Persisting at a task
- ◆ Adapting to changing situations and being receptive to changes in paradigms
- ◆ Processing new information into the current framework
- ◆ Valuing information in an ethical framework
- ◆ Evaluating ramifications and implications of practices

People Skills

- ◆ Teamwork skills for solving problems
- ◆ Negotiation and cooperation for handling discrepancies and conflict
- ◆ Multicultural and gender-difference appreciation and sensitivity
- ◆ Ability to take directions from individuals and agencies in order to achieve a goal
- ◆ Responsibility to protect rights and privileges of other individuals and societies

Personal Qualities

- ◆ Honesty in communication and conviction at tasks
- ◆ Sense of quality, desire for effectiveness and integrity
- ◆ Self-evaluation and commitment to improve skills and qualities
- ◆ Confidence to accept criticism and evaluation from others
- ◆ Positive attitude toward learning for personal and professional development

Added to the requisite technical knowledge, these skills are important for personal and professional interactions that contribute to effective job performance. Strategies for inculcating these skills can be incorporated permanently into a curriculum with significant initial effort. Their evaluation can be readily introduced into existing evaluation methods. *Note:* These skills should be used as teaching goals and not as criteria to exclude students from a career path.

The skills described above have been recognized by employers for years as skills needed for successful job performance. Yet, these skills have only recently become an expressed concern of employers. In the past, college graduates were not always taught to transfer these skills to the workforce. Today, employers are encouraging col-

leges to instill these skills in students within the technical education framework.

Biotechnology and Job Literacy Skills

The biotechnology program at Kingwood College was restructured to make students job-ready, both intellectually and personally. The education of students wishing to prepare for biotechnology careers should include practices that instill and measure nontechnical skills. Biotechnology/bioscience technicians must be creative, thinking, and interacting members of a flexible, goal-oriented team. At the same time, they must be accountable to themselves, employers, government agencies, and the public. The curriculum and evaluation procedures must match workforce conditions.

In the Biotechnology Curriculum

A typical day in a biotechnology work environment involves government regulations, environmental compliance, standardized methods of operational quality control (FDA, 1996), safe laboratory practices as outlined by the Occupational Safety and Health Administration regulations, and accuracy in performing tasks and recording data. Many biotechnology workplaces are adopting benchmarking strategies and total quality management models to improve the workplace environment. Work must be done in a cost-effective manner that guarantees a profit for the company or the best utilization of grant money for the institution. The potential for commercialization of the research requires that employees maintain veracity and secrecy on the project. Students must be taught to be responsible citizens in light of the controversial nature of the work they will be performing.

Strategies for Instilling Skills in the Curriculum

The biotechnology laboratory facility at Kingwood College was designed to model the laboratory conditions students would encounter in industrial and academic research work environments. Many contingencies were designed into the curriculum for remediation of and assistance to underprepared students. Students from underrepresented groups were given the option of mentoring with student peers and faculty.

Equipment and Laboratory Facilities

State-of-the-art equipment purposely was not selected for the Kingwood College Biotechnology Program. Instead,

basic teaching instruments were used to teach laboratory techniques. For example, the college acquired manually operated single-sample spectrophotometers instead of automated dual-beam models. The simple spectrophotometer requires the user to understand the full operations of the instrument. Its use ensures that students will develop a complete understanding of each instrument's components and operation. State-of-the-art computer-integrated instrumentation, software, and protocols were used periodically to reflect the practices of the workforce.

Curriculum Elements

Several projects and requirements were added to the biotechnology curriculum to instill relevant job literacy skills. Students were responsible for managing the facilities and supplies, maintaining the laboratory instruments, monitoring their personal safety practices and records, developing and evaluating laboratory protocols, and participating in team projects. A culminating team project involved the development and full production of a potentially marketable medium-scale biotechnology product.

Distributed throughout the technical content of the curriculum were activities to broaden the students' abilities to use information and to model tasks expected of laboratory personnel in many job settings. Regular assignments required students to use databases of the current literature and to access the Internet to gather information about a topic. Periodic assignments refined the students' biotechnology problem-solving abilities.

Students were encouraged to examine the social implications of the information covered with each new topic and to evaluate the accuracy of the scientific views in the context of the opposition. Students in each class also were assigned a semester-long project: to collect biotechnology information from current newspapers and magazines and to evaluate bias, inaccuracies, and strengths in the reporting.

Evaluating Job-Literacy Skills Components in the Curriculum

Student and program evaluation was an ongoing concern during the development and execution of the curriculum strategies. Evaluation methods and instruments were discussed with students and faculty to ensure accuracy and reliability.

Student Evaluation

Knowledge and skill components were observed and measured in the context of the job literacy needs and the occupational environment. Student knowledge was evaluated using traditional testing methods. Likert scale surveys were completed by the instructor to measure students' behavioral skills and technical skills performance after major assignments. Teamwork and organizational skills were evaluated using a survey completed by the students' peers. This process models the employee performance evaluations used in many academic, governmental, and industrial work settings.

Program Evaluation

Regular meetings of the Biotechnology Program Advisory Board formed the major review process for the program's curriculum, directions, and goals. The advisory board was composed of academic scientists, educators, and industry representatives. Most of the members employed previous program graduates or served as internship partners. Every six months the advisory board was presented with the curriculum and asked to comment and vote on its practicality and relevance to the occupational areas.

It was important to ensure that students' biotechnology skills were marketable outside of the region served by the college; therefore biotechnology companies in other regions were surveyed to see if the curriculum satisfied their employee needs. Another measure was comparison of the Kingwood College curriculum knowledge and skills components to those of other colleges with successful two-year and four-year biotechnology programs.

Students had a part in evaluating the curriculum. Graduates were asked, by letter or telephone, to comment about the relevance of their education. The respondents generally approved of the new curriculum model. Most felt that the skills they learned in the program benefited them on the job and in further undergraduate and graduate studies. They also appreciated the nurturing environment over the selective environment encountered at other colleges or in other programs. Several graduates successfully transferred their skills to other career paths and to locations distant from the college's service region.

Conclusion

The evolution of biotechnology and breakthroughs in genetics are causing a major shift in the job market. Community colleges need to prepare students for careers

using biotechnology. The success of these programs is dependent on the ability of the colleges to instill in students the skills needed for the wide variety of biotechnology jobs. Using input from prospective employers, community colleges can turn classrooms into environments that develop lifelong skills needed for career success.

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23

Growing a Community College Biotechnology Program through Collaborative Partnerships

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Abstract: The process of building a new curriculum for biotechnology technician training at City College of San Francisco demonstrates the power of partnerships in serving both industry and student needs. Internships, mentorships, professional development, faculty fellowships, and industry presence in the classroom are contributing to new ways of teaching and learning. Student placement and industry satisfaction are the rewards for collaborative effort and the justification of grant seed money support.

Relevant discipline: biotechnology

New Program Development

Emerging Biotechnology Technical Programs

Strong community and technical college certificate and degree programs are developing to meet the skills demands of the growing biotechnology industry. Growing evidence supports the premise that building successful community college programs can most productively be done through collaborative partnerships with high schools, biotechnology industries, universities, and national laboratories. The 1990 report *America's Choice: High Skills or Low Wages* predicts a continued need for a well-trained workforce, a prospect that offers exciting opportunities for students who wish to prepare for entry-level positions in this emerging field (National Center on Education, 1990).

Biotechnology Program in San Francisco

The biotechnology technician certificate and associate degree program at City College of San Francisco has evolved through collaborative partnerships. As a result of the network of educational and industry partners, multiple perspectives have merged to create improved ways of teaching science, math, and technology. Sharing of expertise, equipment, and enthusiasm has snowballed into a variety of forums for exposing the public and policymakers to the important role of community colleges in facilitating dissemination of scientific information and generating interest in the genetics revolution.

Historical Perspective of City College

City College of San Francisco is 60 years old and currently serves close to 70,000 credit and noncredit students. Located in a large urban setting, the college is faced with the challenges associated with inner-city issues of poverty and crime. More than half of the students are from under-represented populations, large numbers are new immigrants, and many are first-generation college attendees. City College is committed to serving the educational needs of the community for both occupational training and transfer to four-year colleges and universities.

Location of the Biotechnology Industry

The San Francisco Bay Area lies in the heart of the young biotechnology industry, with more than 200 biotechnology companies in addition to major research facilities. With such a concentration of resources, the faculties of chemistry and biology at City College of San Francisco were eager to collaborate in the development of a unique

program for educating biotechnicians that continues to evolve into a cutting-edge school-to-career science curriculum. The program includes internships for both students and faculty, the participation of industry scientists in classroom laboratories and lectures, and inclusion of the National Skill Standards for the Bioscience Industry (Education Development Center, Inc., 1995). In addition, it provides a seamless pathway from high school into the biotechnology certificate and associate degree program, coupled with transfer possibilities to four-year colleges and universities. As the program continues to evolve, new networks are resulting in multiple community college consortia, teacher education, community outreach, and connection with the Human Genome Project.

The complexity of the program becomes evident in the evolution of the biotechnology certificate program from conception four years ago to its present implementation and future vision, including expanding partnerships with other community colleges. The creation of an appropriate curriculum and delivery system that would satisfy both industry and educators within the Tech Prep framework was necessary. Further considerations involved the relationship to the School-to-Work Opportunities Act, Goals 2000, and related legislation. Compliance with the science framework and curricular guidelines in the state of California added yet another layer of accountability.

Foundation for a New Biotechnology Program

The Beginning of a Dream

The excitement surrounding the emerging biotechnology industry served to fuel enthusiasm for developing a curriculum that would prepare students for entry-level positions in this field. Federal funding in the form of Tech Prep money resulting from appropriation from Title III of the Carl D. Perkins Vocational and Applied Technology Act (U.S. Congress, 1990) served to support curriculum development, partnership with high schools, and staff development. With a limited equipment budget, the acquisition and maintenance of essential equipment has been a major challenge. As industry partners recognized this need, they supplied some equipment. Faculty members and administrators at the college began to seek external funding and review institutional capabilities. It quickly became clear that collaboration was

required to develop a rigorous program that would prepare students for biotechnology careers.

Laying the Groundwork

Key stakeholders in the developing biotechnology program were identified. Besides the City College of San Francisco, these included San Francisco Unified School District and several industry partners. Not only external players were needed, but internal partners also were required. A new working relationship between the chemistry and biology departments has proved to be one of the unexpected benefits of the biotechnology program.

Extensive work with high school faculty members in both biology and chemistry also has proved to be of great benefit. As a result of these working relationships, the college has changed the time of course offerings to accommodate high school students who wish to earn college credits while they are still in high school. A particularly popular college course, Briefing in Genetic Engineering, provides an overview of the biotechnology industry featuring guest experts. High school students who are recommended by their science teachers can earn both high school and college credits for the course, have tuition waived, and gain registration priority for future college courses. High school teachers actively participate in the course by providing lectures, demonstrations, and hands-on exercises. Teachers are also invited to accompany students for industry-led presentations that stress skills required for entry into the emerging field of biotechnology.

Determining National and Local Industry Needs

Grant-funded industry surveys and interaction with the program advisory board provided local information regarding industry needs for entry-level technicians. Because of the emergence of this industry from the scientific research community, the biotechnology companies often used persons with advanced degrees to perform technician tasks. Only recently is there a growing interest in more clearly defining entry-level skills requirements.

The National Skill Standards for the Bioscience Industry provided national guidelines. Faculty members in the biotechnology program participated in the National Skills Standards Project and will continue to be a part of the project's ongoing evaluation. Equipped with both national and local biotechnology industry skill sets and personal experience, partners collaboratively began

the task of creating a curriculum to satisfy the curriculum committee of the college, the requirements of the Tech Prep initiative, and industry. Both industry and educators are developing a mutual understanding of how to provide training.

Professional Development

Biotechnology Skills Training

Biotechnology training, funded by the National Science Foundation (NSF), was provided for high school and community college faculties. As a result of this training in laboratory techniques for biotechnology, the content and form of delivery have changed to include more hands-on and industry-related experiences for students. Industry scientists have also provided laboratory training for both students and teachers. Some of the workshops were supported by Tech Prep funding. Internships and fellowships for community college faculty at Lawrence Berkeley National Laboratory have been another way of increasing skills levels. Networking using the Internet is beginning to provide updated sharing of “what is new” and “what works.” National conferences such as The Genetics Revolution, Workforce 2000, and the National Institute for Staff and Organizational Development (NISOD) have provided opportunities for growth and networking. As faculty members have become involved in building new programs, they have taken on new roles that include grant writing and management, and working and teaching with industry partners.

Designing a Curriculum

Tech Prep Articulation

The biotechnology curriculum design requires development of comprehensive technical preparation in biotechnology with a nonduplicative sequence of courses spanning the junior and senior year of high school and articulating into two years of postsecondary work at City College of San Francisco. The community college program provides a certificate indicating mastery of technical, scientific, and job-related skills necessary for entrance into the Bay Area’s rapidly growing biotechnology industry. City College of San Francisco developed a series of new courses that integrate academic and vocational education within the biotechnology context. New college courses include two semesters of chemistry, two semesters of biology specifically geared for biotechnology, and a new bioethics course. Students become proficient in

the use of micropipettes and making solutions and dilutions. Mathematical skills are enhanced through working with actual samples. Running and interpreting agarose gels becomes routine. Electrophoresis, chromatography, microscopy, and tissue culture techniques are all embedded in the laboratory experiences. Interwoven in the curriculum are good manufacturing practices (GMP) and good laboratory practices (GLP). There is the expectation that students who participate in the biotechnology program will also gain competence in the skills identified by the Secretary’s Commission on Achieving Necessary Skills (1991), which include the following:

- ◆ Ability to organize and allocate resources
- ◆ Ability to work as a member of a team
- ◆ Ability to acquire and use information
- ◆ Understanding of complex relationships
- ◆ Ability to choose and apply technology to task

Electives and work-based experience supplement the required courses. Students can also fulfill general education requirements for an associate of science degree. Although the curriculum is designed to provide skills for entry-level biotechnicians, it also provides a strong foundation for students who wish to continue with their formal education.

Industry-Education Partnerships

Collaboration between educational and industry partners is essential for maintaining quality in a curriculum. Since the cultures of industry and the college differ, such collaboration requires cross-cultural exchange and mutual adaptation. Time, energy, and persistence were required to build a program that can be considered world class.

During implementation of the biotechnology program, some of the following lessons were learned:

- ◆ Identifying the key stakeholders involves networking and considerable time.
- ◆ Obtaining commitment from middle management is easier than from the top administrators of companies.
- ◆ Building trust over time is a critical part of the development of a strong program.
- ◆ Being flexible and making continuous adjustments are absolutely essential.

- ◆ Starting small and growing over time is a useful approach.
- ◆ Empowering of participants results in ownership and contribution to the quality of the program.
- ◆ Acknowledgment of time and energy commitment is appreciated and deserved.

Providing Instructional Support Services

It is well known that student success for underrepresented groups in science and math has been poor. Providing support services for access and success of special populations is one of the goals of this project. The creation of a summer bridge program is in the developmental stage. It is strongly supported by both the high school and college science departments. Funding issues continue to plague the developmental process, but as interest grows, the bridge program seems more plausible.

Marketing the Biotechnology Program

Strategies for informing students about the program have included visits to high schools, introductory sessions at the college, field trips, and career decision processes involving parents and students. Members of the faculty and counselors at City College advise students that this program would be an exciting and viable option. Engaging industry was a slow process. Biotechnology companies are beginning to hire community college graduates, however, and to offer them internships.

Ongoing Program Enhancement by National Laboratory

A recent Community College Initiative (CCI) has been funded by the DOE to provide assistance to 10 community college biotechnology students to attend summer residential workshops that prepare them for internships at Lawrence Berkeley National Laboratory and to support fellowships for community college faculty. Such commitment demonstrates support for the community colleges as they continue the development, implementation, and evaluation of biotechnology programs.

Providing Accountability

Evaluation Processes

The college has a formal program review process in place with clear and defined emphasis on improvement of the quality of teaching and learning. Emphasis is placed on relevance and collaboration among departments within the college as well as on expanding external partnerships. The Tech Prep grant also has a formal evaluation process. Qualitative evaluation must be a large part of the process because there are so many unexpected barriers and benefits. Job placement and success are indicators that hold weight with prospective students. Side benefits continue to abound. New equipment, dedicated space, renewed enthusiasm, and new relationships are only a few examples.

Sharing Some Success Stories

Some graduates of City College of San Francisco biotechnology program have been placed in jobs and some transferred to other institutions for additional training. Because some of these students more than likely would not have been able to enter this industry without the benefit of this program, their successes are special and heartwarming.

Graduates have demonstrated a willingness to come back and share their stories. These students are role models for current students. They provide yet another vital link between the college and industry. Their experiences and feedback aid in program improvement.

Expanding the Network

City College of San Francisco is part of a consortium whose mission it is to advance biotechnology education throughout the nation's community colleges and secondary schools. City College has taken a leadership role in efforts to build an infrastructure for sharing information and a nationwide clearinghouse for biotechnology educational materials; in addition, it plays a leading role in facilitating partnerships in biotechnology. It also is actively involved in economic development activities and is the site for the Northern California Center for Applied Biological Technologies, funded by the California Community College Economic Development Network (ED>Net). This regional center's goal is to serve as a point of contact for industry and community colleges, coordinate activities, and accelerate the development of community college biotechnology programs.

Reflecting on the Process and Product

Building a biotechnology technician training program in a very diverse urban setting has revealed the power of partnerships. The people committed to the biotechnology program at City College of San Francisco believe that students are learning rigorous academic material in a setting that also provides occupational skills. The support of industry and national laboratories offers incentives for students and teachers to continue to learn and grow. As a result of true collaboration, the impact of growing a community college biotechnology program in San Francisco is being felt throughout the educational system and the community at large.

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24

An Applied Biotechnology Capstone Course: Melding the Resources of the Community College and Industry

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Abstract: Biotechnology Instrumentation is a course that exposes students to techniques used in the biotechnology industry. Instruction is divided into modular protocols designed and taught by representatives from the biotechnology sector. The community college teacher serves as a coordinator recruiting students, finding and supervising industry instructors, and assessing course progress. Since the course was implemented in 1994, nearly all equipment and reagents have been loaned or donated by industry, and graduates have obtained part- and full-time positions in biotechnology.

Relevant discipline: biotechnology

Historical Groundwork to Embark on Course Design

The Biotechnology Instrumentation course is a partnership between San Diego City College and the local biotechnology industry community. In 1986, perceiving the impact of biotechnology on science education and its entrepreneurial growth in San Diego, a biology teacher from City College and a regional sales manager from a national biotechnology firm with past community college teaching experience teamed to conduct a three-month series of interviews of representatives from 15 local companies and research institutes. The survey indicated a need to develop, in conjunction with industry, a two-year college curriculum for entry-level biotechnicians.

Following a lengthy period of unsuccessful grant proposals and attempts to address concerns including equipment expense, academicians involved in vocational programs, articulation with universities, potentially competitive programs in the area inside and outside the multi-institutional San Diego Community College District, and student recruitment and eventual job placement, the biology faculty at City College received approval to begin planning a curriculum. Keys to getting the go-ahead for course preparation were a concerted departmental commitment to biotechnology education, a dialogue with community college counterparts initiating similar efforts around the country, a site visit by the chancellor and top district officials to a biotechnology company, the continued growth of the industry locally and nationally, and the willingness of a company, Stratagene Cloning, Inc., to sponsor faculty internships and to loan essential startup equipment.

In late 1993, a biology faculty member with intra and interdisciplinary team teaching experience began a five-month internship at Stratagene. His mentor was a technician responsible for the design of educational kits who had graduated from the longest-running Californian community college biotechnician program at Contra Costa College in the San Francisco Bay area. The 10-year-old biotechnology program at Contra Costa focuses on a capstone course with prerequisites primarily in chemistry and biology. The bulk of the capstone instruction is divided into modular protocols designed and taught individually by representatives from the biotechnology sector. A community college teacher serves as the course coordinator. Following a week of on-site evaluation at Contra Costa, a decision was made to adopt the Contra Costa basic approach for City College.

The advantages of the faculty-coordinated, industry-instructor, serially taught Contra Costa program and, subsequently, the one at San Diego City College include cost effectiveness (i.e., industry instructors provide state-of-the-art equipment and most reagents); contextualized, updated technician training by industry representatives who serve as primary role models; accelerated marketability of community college biotechnician training programs as a result of fusing the college and industry into an interactive network; and freeing the coordinator to concentrate on minimizing the potential disadvantages of this approach.

The disadvantages of these programs, which have not been totally overcome, are lack of pedagogical experience of most instructors, especially with groups of adult learners with little or no vocational background; student adjustment to instructors of different teaching styles; frenetic pace (successful students report spending an average of 30 hours per week in classes, laboratories, and studying) and potential discontinuity of the course because each module is taught by a different instructor; and dual demands and priorities of the coordinator and instructors potentially increasing class stress levels.

Instructor and Student Recruitment

Biology Instrumentation is a six-unit course, first offered in the fall semester of 1994 and subsequently offered every fall to students having successfully completed a minimum of one year of inorganic chemistry, a semester of general biology, and a semester of microbiology. Sessions run formally four hours, three times a week in the evening, to accommodate the industry instructors' work schedules. Industry instructors are paid honoraria, and the coordinator is the instructor of record. Funds allotted to City College from the Vocational and Applied Technology (Carl D. Perkins) Act of 1990 are used to pay the honoraria and grant the coordinator release time from other instructional duties.

Instructors have been employees of nine biotechnology firms in the area, research units of two universities, and the Salk Institute. They are recruited not only to reflect the diversity of methodologies practiced but to market the Biological Instrumentation course to a wider spectrum of the biotechnology community. Prospective instructors are interviewed and selected by the coordinator. It is imperative that instructors have a clear understanding of a technician's work. Most of the instructors supervise technicians or are themselves technicians without advanced degrees.

The majority of instructors have little or no teaching experience prior to their involvement in the San Diego City College course. Through weekly visits to the companies and electronic mail correspondence, the coordinator establishes a pedagogical dialogue with instructors. The coordinator explains construction of learning objectives, provides a general format for printed protocol design, reviews first drafts of instructor-designed protocols, discusses the realities of laboratory class management and assessment, and promotes an exchange of ideas and further melding of pedagogical with occupational perspectives.

The coordinator recruits students a year in advance to provide counseling opportunities for prerequisite course planning. Students are recruited through coordinator presentations in prerequisite courses, advertisements in semester schedules of classes, publicity in the local newspaper, referrals from university faculty, and word of mouth in the biotechnology community. Prospective students are asked to complete a questionnaire detailing their academic and vocational background and aspirations. The questionnaire has been used as an application for admittance to the course and an instrument to predetermine the heterogeneous composition of laboratory work groups. Students are polled also on the amount of time they can devote to the course and their willingness to give and respond to weekly evaluation. Students must obtain the permission of the coordinator to add the class.

A pre-semester party with staged activities has been held in successive years at the homes of biotechnology executives and course coordinators to introduce students to each other and industry instructors. The ice-breaking party initiates a validation process welcoming students, instructors, and coordinator into a novel learning community requiring an intense semester-long commitment and reshuffling of priorities.

The 48 students enrolled in the course in the first three fall semesters reflected the variety of cultures and the age distribution found in downtown urban community colleges such as San Diego City College. Students enrolled to seek full-time entry positions in biotechnology or part-time jobs while continuing their education. Some were already working in the industry and sought to upgrade their skills.

Course Activities

In the first week of the class, students take a diagnostic test to identify potential weaknesses in their conceptual foundation that could be fortified before experiencing the industry-taught protocols. Also in the first week of classes, students may tour biotechnology industries, where they observe many of their instructors working and discuss job placement strategies with human resource representatives. Additional tours are to a college computer lab where an industry instructor shows students how to obtain biotechnology and job-related information from the Internet and to a university biomedical library, where the coordinator introduces students to computerized information retrieval systems that enable them to conduct literature searches. The first week culminates in the first protocol presentation by an industry instructor who introduces good laboratory procedures (GLP) and reagent preparation.

Most teaching stints are three class sessions. Usually, instruction is conducted by a single industry representative. Occasionally, however, pairs of instructors with complementary teaching styles present overlapping methodologies. The coordinator works with the instructors to establish a curriculum that communicates a sense of continuity among the methodologies presented. In subsequent weeks, students examine methodologies associated with the analysis and manipulation of genetic material and the purification and identification of proteins. The sophistication of techniques showcased in the course is not typically taught at the lower division level.

The coordinator typically directs the first few minutes of each session to infuse topicality, continuity, and an opportunity to reestablish bearings in such a rapidly paced, multiply taught course. In 1995, this prefatory phase, the Coordinator's Corner, was scripted in outline form on the overhead projector to utilize time efficiently. Coordinator's Corner topics typically include national and local news in biotechnology, new job listings, pertinent upcoming public seminars and symposia, assignment deadlines, reception of new library reserve books, and review of past and preview of upcoming protocols. The corner also serves as an instant sounding board for coordinator and student concerns that may surface throughout the course.

Teaching styles vary, but through consultations with the coordinator, an instructional pattern has evolved that typically begins with a short quiz serving as a gauge of student preparation and a preliminary forum for

methodological remarks, followed by a lab activity. The instructor then discusses the conceptual underpinnings of the activity in a minipresentation not exceeding 30 minutes followed by some form of assessment. Instructors have demonstrated creativity in their assessments: A number of them developed scenarios for case analyses; several used company catalogs as teaching and evaluation tools; and one devised a Jeopardy game assessing knowledge of different aspects of the polymerase chain reaction.

Industry usually supplies all the equipment and reagents for the courses. Consequently, the biology department's supply budget was not taxed by offering a lab-intensive, applied academic course using state-of-the-art equipment. (A budget of \$1,500 to \$2,000 per course offering is recommended, however, to supply any reagent or equipment needs that industry cannot furnish.)

The Critical Role of Assessment

Assessment is the key to continuous quality improvement and innovation. Students take pre- and postlaboratory quizzes designed and evaluated by instructors. They maintain "industrial-style" laboratory notebooks and are given notebook scoring rubrics the first week of class. Students submit a three- to six-page analysis of each protocol a week after its completion. Each protocol analysis contains the following components:

- ◆ List of methodologies learned
- ◆ Purpose of each methodology
- ◆ Principle underlying each methodology
- ◆ Troubleshooting tips
- ◆ Exemplary data and interpretation
- ◆ Abstract
- ◆ Job function identification and illustration
- ◆ Attribute reinforcement

For the last two components, students use a menu of 14 job functions and 35 desirable attributes associated with a "Bioscience Technical Specialist I" as identified in Skill Standards for the Bioscience Industry (Gateway, 1995) covering entry-level technical workers in pharmaceutical companies, biotechnology companies, and clinical laboratories. Students cite experiences of using the protocol to justify their job function and attribute designations.

Protocol analyses form the core of a student portfolio that includes a cover letter identifying the value of

each insert, a chronological justification of the order of protocols, a key reagent spreadsheet linking the roles of major chemical materials with particular protocols, and a summary analysis in which students devise a novel way to relate the protocols to each other. Additional elements in the portfolio include student critiques of new biotechnology books, lab manuals, and methodological tapes; diagnostic test and quiz corrections; extra seminar reports; and a résumé. Each student also inserts video snapshots (taken by the coordinator) of their interactions in class and performance evaluation comments and recommendations made about them by industry instructors and the coordinator. The goal of the portfolio is to demonstrate the students' success in the Biological Instrumentation course in a meaningful instrument they can use as they apply for entry into industry or further educational studies.

Students are assessed two times during the semester on reports of public seminars they attended at research institutes and biotechnology companies. Students are given written suggestions by the coordinator on what they should do before, during, and after the seminar to maximize the worth of the experience. Students present short oral reports and submit documentation that includes a summary of their preseminar literature preparation, an outline, description of the visuals used in the seminar, illustration of six components commonly mentioned in a seminar (hypotheses, basic techniques, experimental designs, controls, results, and future research), a list of definitions, an abstract, and a personal evaluation of the experience. Seminar experiences are intended to provide additional opportunities for students to receive and communicate technical information as well as to initiate students into the milieu of professional science.

Near the end of the course, sessions address the regional status of biotechnology companies and their projected requirements for entry-level biotechnicians (Southern California Biotechnology Industry Needs, 1995) and biotechnology job-hunting stratagems. Several industry instructors are invited to conduct mock interviews of students answering advertisements for positions with hypothetical job descriptions.

Students also serve as assessors. They complete a six-page rating form of each instructor that is submitted with each protocol analysis as well as a 27-page rating evaluation of all course components. On the final day, students individually give their videotaped impressions of the course and advice for prospective students as well as participate with the coordinator in a focus group evaluation.

Instructors complete a self-evaluation (similar to the six-page student rating) at the conclusion of their respective stints. They identify those job functions associated with a Bioscience Technical Specialist I that are reinforced by the protocol they teach.

The coordinator fills out a similar six-page rating form on instructor performance and student interaction, as well as perceptions of job functions reinforced by the protocol. The coordinator videotapes segments of each instructor's session and writes an instructor evaluation. Instructors and coordinator meet once a year to assess lessons learned from the past course offering and plan the curriculum for the upcoming semester.

Course Outcomes

Although still developing, the San Diego City College Biotechnology Instrumentation course has taken significant strides. Beginning with the fall of 1996, graduates of the program with additional coursework in computer science are eligible for an associate of science degree in applied biology. Company partners have loaned and donated equipment to create and support the course, making it unnecessary to rely on external grants or infusion of district equipment funds.

Before this effort, local industry had little concept of the role the community college could play in serving its entry-level needs. Students who have completed the Biotechnology Instrumentation course have obtained employment at many area companies because of referrals by industry instructors and their own confidence in their ability to learn protocols quickly and positively interact with a wide variety of supervisors. Many graduates who were already working in the industry have found more desirable positions. Other graduates have gained acceptance into professional programs that had rejected them before, and one student earned a fellowship to work at a national laboratory.

In the fall of 1996, similarly run courses were inaugurated at two other colleges in the area. The three-college cooperative, using industry instructors with evaluated teaching experience, ensures further opportunities to improve each program and respond better to regional needs for entry-level technicians.

Conclusion

The Biotechnology Instrumentation course represents a learning dynamic for everyone involved. Students are introduced to industry-prioritized protocols, skills, and attributes, and receive feedback on their conceptual and manipulative performance and overall job worthiness; industry instructors become sensitized to the community college as a potent training environment and through extensive feedback on their teaching improve their roles as industry trainers; in addition the coordinator learns the entry-level training priorities of the bioscience industry and becomes more effective at teaching how to teach. Biotechnology Instrumentation illustrates how cooperative ventures between two-year colleges and the biotechnology community empower and contextualize science education.

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25

Biotechnology at William Paterson College: Educating Students for the Genetics Revolution

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Abstract: A biotechnology program was developed at William Paterson College (WPC) involving a multifaceted approach to bringing biotechnology into the secondary, undergraduate, and graduate curricula. Summer and weekend workshops were developed for training high school teachers in various aspects of molecular biology and biotechnology. The unique Mobile Biotechnology Laboratory was developed to deliver equipment, reagents, supplies, and technical assistance to New Jersey high schools, many of which did not have the resources necessary to carry out the laboratory component in these areas.

Note: Recommended course sequences for a baccalaureate or master's degree in biotechnology may be obtained by writing to William Paterson College.

Relevant disciplines: biotechnology, genetics

Introduction

The genetics revolution, which began with the development of genetic engineering and related biotechnological techniques in the 1970s, has resulted in a serious need for educational programs and opportunities to retrain secondary school teachers in the new discipline and to introduce secondary, undergraduate, and graduate students to genetics and biotechnology. The need for educational programs in biotechnology is twofold: first, to encourage students to pursue careers in science, it is necessary to expose them to exciting, innovative areas as early as possible; second, for students with little or no interest in science, it is critically important to provide a basic understanding of the genetics revolution. Recent court decisions of national interest and developments in several areas, including clinical genetics, oncology, and virology, reinforce the importance of all citizens understanding the basic principles of molecular biology, genetics, and related topics. The unique program for biotechnology education at William Paterson College involves a multifaceted approach to bringing biotechnology into the secondary, undergraduate, and graduate curricula.

Biotechnology Workshops

Over the course of several years, students from area high schools had attended special laboratory sessions at WPC exposing them to different areas in biotechnology. This was not a formal program; it was initiated by area teachers who wanted their students to experience state-of-the-art technology for one or two periods during the semester. Teachers brought their classes in for hands-on sessions in the Biology Department laboratories to experience DNA cloning, DNA gel electrophoresis, restriction digestion of DNA, microbiological lab exercises, and other lessons. It was clear from that experience that high school students had an interest in hands-on biotechnology and that many teachers were motivated to find out more about the emerging field.

The first formal hands-on workshop in biotechnology for high school teachers was offered as a two-week summer institute in 1984. Several teachers worked with biology faculty to develop the High School Biotechnology Program. William Paterson College continues to offer summer programs and weekend workshops in biotechnology to interested secondary school teachers.

Mobile Biotechnology Laboratory

A grant from the New Jersey Department of Higher Education led to the development of a program designed to bring facilities and expertise for biotechnology to the high schools. In the Summer Institutes in Biotechnology, modules were developed jointly by WPC faculty and local high school teachers specifically for incorporation into high school biology classes. Teachers adapted each module to the level of their students' abilities. These training programs provided extensive written material and practical laboratory experience. Because many schools did not have appropriate facilities, WPC provided participants with a mobile biotechnology laboratory fully equipped with the appropriate instrumentation and supplies, and staffed by a biotechnician. Every teacher who completed the two-week training program was expected to use the resources in the Mobile Biotechnology Laboratory for up to two weeks during the academic school year. Each teacher agreed to implement one or more of the modules in the classroom during the school year.

Four modules were developed for this program. Each one was taught in an intensive one-week workshop and included both theory and hands-on experience. The protocols were carefully developed so that they could be easily introduced into the high school curriculum. Helpful hints were discussed and emphasized, such as points in the procedure where the protocol could be stopped, how to troubleshoot technical problems, and how to teach various aspects of the protocol. The four modules are as follows.

Isolation of DNA and Electrophoresis of Nucleic Acid Fractions

This module involves the isolation and purification of DNA from *E. coli* bacteria. Cells are lysed, DNA is precipitated and spooled onto glass rods, resuspended in buffer, and digested with restriction enzymes. *E. coli* DNA and other samples of plasmid, phage, and genomic DNA are analyzed on agarose gels. Centrifuges, electrophoresis equipment, and micropipettors are used in this module.

Recombinant DNA: Cloning DNA into Plasmid Vectors

This module involves restriction digestion of phage and plasmid DNA with the same restriction enzyme. Phage fragments are combined with the restricted plasmid vector, which is ligated and used to transform bacteria.

Bacterial transformants are screened for the presence of recombinant plasmid using replica plating and antibiotic resistance. Discussion of theory and principles of cloning is included. Microbiological techniques are used extensively, using disposable replica platers and micropipettors.

Immunodiffusion and Enzyme-Linked Immunosorbant Assays (ELISA)

Antibody/antigen reactions are discussed and demonstrated. Ouchterlony immunodiffusion is performed with various antigens and antibodies. ELISA assays are performed to test for presence of specific antigens and to determine antibody titers. Equipment includes a multi-well plate reader for the ELISA assay.

Isolation and Analysis of Proteins

Protein extracts are prepared and purified using column chromatography. Large gel filtration columns are used for demonstrations of the technique, and the separation of molecules is monitored by ultraviolet spectroscopy. Minicolumns are run individually with colored samples (dyes) of varied molecular weights to demonstrate molecular separation during column chromatography. This highly visual technique is useful for students to learn principles of biochemical separation.

Impact

In the course of the three years supported by the grant, 63 high school teachers were trained. It is estimated that over 1,000 students benefited from the Mobile Biotechnology Laboratory during those years. In addition, the experience gave the teachers confidence in their ability to learn the new technology and incorporate it into their class curricula. Subsequently, many of the teachers were able to purchase equipment and supplies and continued to utilize the modules or related lab exercises in their curricula without additional support from WPC personnel. The actual effect of this program is ongoing and has had an impact on many thousands of students through their retrained teachers.

The use of the Mobile Biotechnology Laboratory was modified when the grant ended. In subsequent years WPC offered workshops and loaned equipment to schools interested in implementing the modules. Schools were required to provide their own reagents, supplies, and technical assistance. WPC faculty continued to be involved in initial training and in a consulting capacity.

Interestingly enough, not long after this program was initiated, the Advanced Placement Course Description in Biology, published by the College Entrance Examination Board, revised its curriculum to include topics and laboratories in molecular biology. One laboratory session (out of a total of 12) is in molecular biology, with exercises on transformation of *E. coli* with recombinant plasmids, restriction digestion, and gel electrophoresis of DNA. These exercises are equivalent to modules developed for the Mobile Biotechnology Lab Program. In the lecture portion of advanced placement (AP) biology, 25 percent of the material falls into the category "Heredity and Evolution." Within that category (and a total of 9 percent of the whole course) is molecular genetics, including RNA and DNA structure and function, gene regulation, mutation, viral structure and replication, and nucleic acid technology and applications. In response to these curricular changes in advanced placement biology, several companies have developed moderately priced kits and equipment to allow schools access to these techniques. These developments affected the target audience of WPC workshops in two ways: It encouraged more teachers to include these topics in advanced biology courses, and it made it possible for teachers to implement the new technology with confidence and with very little monetary investment.

The Future of Biotechnology

WPC envisions a continued interest in programs in biotechnology to retrain teachers at the undergraduate and graduate level and to prepare the next generation of scientists to meet the challenges of the genetics revolution. WPC continues to offer weekend workshops with new topics being developed as the discipline evolves. A new workshop on polymerase chain reaction (PCR) was offered recently. In the last few years, many school districts have lost large numbers of science teachers to retirement and many new teachers have entered the ranks. This should lead to a resurgence of interest in and need for workshops for science and particularly for workshops in biotechnology to prepare new teachers for this field. The special emphasis on biotechnology and molecular biology recently introduced into the AP biology courses also illustrates the significance of these areas. Teachers will require this expertise to confidently approach the newly developed curricula.

One compelling question that should be addressed in the future concerns the importance of educating the

general community in new advances in genetics. Educators will need to determine whether all high school students should be exposed to more enriched curricula in genetics, molecular biology, and applications. In light of the increasingly important role played by these new technologies in modern society, it is important for the general public to have a deeper understanding and appreciation of the power of biotechnology and of ethical considerations related to this discipline. Community colleges and four-year colleges will need to consider the role of the genetics revolution in science courses for nonscience majors as well as for science majors. Future politicians, lawyers, factory workers, homemakers, parents, and many others will need to be familiar with the new technologies and their implications in order to make educated decisions involving themselves, their families, and their communities.

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PART IV

Multidisciplinary Approaches

26

A Multidisciplinary Approach to the Human Genome Project

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Abstract: Mapping the human genome will reinvigorate important philosophical questions about the nature and meaning of human life and call forth the possibility of manipulating the behavior of human beings. A meaningful discussion of these issues could occur most effectively in a multidisciplinary context. The multidisciplinary course at the University of Wisconsin Center–Waukesha, provides students with an integrative view of the Human Genome Project by exploring the perspectives of three very different academic disciplines: biology, philosophy, and psychology.

Relevant disciplines: biology, philosophy, psychology

Background and Rationale

The Human Genome Project promises to generate a complete map of the human genome by the year 2005. That map will revolutionize clinical medicine by providing tools for expanded genetic screening and therapy. It will reinvigorate debate about troubling philosophical questions concerning the nature and meaning of life, and it will pose the possibility of manipulating the behavior and personalities of individual human beings.

Confronting the pervasive and perplexing implications of the HGP presents both a challenge and an opportunity. It is important to explore the scientific richness of the HGP, but it also is necessary to tackle the inherent and often troubling ethical and philosophical concerns it raises. In this context, the traditional discipline-specific approach characteristic of higher education is inherently problematic. That approach contributes to and reinforces the difficulty students have in making connections and in discerning relationships. Too often, they fail to appreciate the unity and interdependence of knowledge, and only with great difficulty do they construct an integrative and synthetic understanding of what they have learned. Furthermore, the HGP does not fall nicely into a disciplinary niche. The questions it raises span the domains of biology, philosophy, and the behavioral sciences. Therefore, the HGP provides an opportunity to develop a multidisciplinary course that emphasizes interaction rather than exclusion, that highlights issues that cross disciplinary boundaries, and that values complexity over simplification. It is important to show our students how a question or problem can be viewed in different but equally legitimate ways, how reasonable people can reach different conclusions, and how complex issues are often not easily resolved. Quite simply, there is value in challenging students to discover connections and relationships and merit in their understanding that there is a commonality implicit in the diversity that constitutes a liberal arts curriculum. In a broad sense, a multidisciplinary course can help to demonstrate something of how philosophy, biology, and psychology speak to the human condition and grapple in different ways with life's fundamental problems and questions.

Value for Students

In the multidisciplinary course *Exploring the Human Genome Project and Its Philosophical, Biological, and Behavioral Implications*, students accrue several distinct

benefits. First, they learn about the HGP and its implications for individuals, such as the expanded availability of genetic screening. Second, they begin to think about ways in which the information developed through the HGP may be used to cure disease and to select human traits for beneficent as well as malevolent ends. But more important, they come to understand how different disciplines speak to the issues engendered by this scientific effort. Students leave each class with more questions than answers, and more uncertainty than certainty.

Value for Faculty

The challenge of developing a course like this one is beneficial for instructors as well, because it forces them to take a different point of view, to think about the connections and commonalities, and to move beyond their disciplinary constraints. This experience enriches their perception and understanding, and ideally it carries over into other courses they teach.

The curricular demands of undergraduate education offer little opportunity for the enrichment that can come from working with colleagues in other disciplines. However, these experiences often prove professionally and personally invigorating and therefore are beneficial to faculty members as well as their students.

Course Objectives

By its very nature a multidisciplinary course has several objectives. Through the interaction that takes place in the classroom, different perspectives are presented and the artificiality of disciplinary boundaries becomes apparent.

Exploring the Human Genome Project has four main objectives:

- ◆ Presentation of the biological facts of the HGP
- ◆ Identification and discussion of the theoretical, psychological, and philosophical implications of the project
- ◆ Formulation of policy recommendations for implementation of the findings of the project
- ◆ Development of a reasonable personal response to the project

The Biological Facts

Without an appreciation of basic biology and genetics, it is difficult to have a meaningful discussion of the HGP. Thus this course begins with the fundamentals of basic biology and genetics to pave the way for meaningful discussions of the HGP. Students read the Department of Energy's *Human Genome Program: Primer on Molecular Genetics* and selections from Thomas Lee's *The Human Genome Project: Cracking the Genetic Code of Life*. These texts and classroom instruction help students gain a basic understanding of chromosomes, genes, the DNA molecule, nucleotide sequences, amino acids, mRNA, DNA amplification, DNA markers, genome maps, and genotypes and phenotypes. As the course continues, these concepts are used and reinforced. There is no attempt to compress an entire course in genetics into a few weeks; instead the goal is to try to give students sufficient background in the vocabulary and the concepts so that they are able to understand the biological basis of what follows.

Theoretical Implications

Once the genetic knowledge base is presented, the course moves to issues that are fundamentally philosophical and psychological in nature. The issues of free will, determinism, emergent properties, nature versus nurture, genetic disease, eugenics, patenting life, and animal rights are discussed. To what degree are properties such as consciousness logically dependent upon biological properties? Can human purpose be explained in biological terms? Is intelligence heritable? Clearly, such topics fall at the intersection of our disciplines.

Policy Considerations

The HGP will make genetic screening possible for a wide range of medical and behavioral disorders. It will enable testing of specific populations for particular genetic defects, and eventually it will yield the technology needed to modify the genome or edit mRNA. Should these technologies be available to everyone? Who will pay for them? What guidance do individuals need to use wisely the information that genetic technology makes available? What if the desire for genetically healthy offspring conflicts with the need to preserve the variability of the human genome? Raising these questions focuses students' thinking on the pragmatic implications of the

basic science. Two excellent texts covering these multidisciplinary concerns are George Annas and Sherman Elias's *Gene Mapping: Using Law and Ethics as Guides* and R. C. Lewontin's *Biology as Ideology*.

Ethical Relativism

One theoretical issue that inevitably arises in a course of this sort, in which moral concerns are being discussed, is the issue of ethical relativism. Because there will be moral disagreements among the members of the class, some students will be led to conclude that there is really no right or wrong answer to moral questions and that everyone's opinion is as good as everyone else's. It is important not to avoid discussing this view. Ethical relativism is one moral theory among others. There are serious problems with this theory and these problems should be pointed out. Meaningful moral discussions should have the facts straight. Moral views about the implications of the HGP that are ignorant of the biology are simply irrelevant. Furthermore, moral views should take into account certain moral principles such as beneficence, nonmaleficence, justice, and autonomy. Consistency and coherence are essential to any position. It may be true that there can be differences in moral conclusions, but it is not true that one moral opinion is as good as another one.

Formulating a Personal Response

The third objective of the course focuses on formulating a reasonable personal response to the project. How are the findings and implications of the project integrated into the student's worldview? The course, for example, considers not only the appropriate guidelines for screening for Alzheimer's disease but also asks the student whether he or she would undergo such testing. If human growth hormone decreases some of the effects of aging, would he or she take it? Ideally students' experiences in this course will enable them to formulate a well-reasoned response to these and similar issues.

Disciplinary Perspectives

How do individuals trained in very different academic specialties view the HGP? What concerns are unique to each discipline? Thoughtful observation reveals that biologists, psychologists, and philosophers tend to focus upon the questions raised by the HGP in slightly different, but related, ways.

The Biological Perspective

The HGP is the first large-scale scientific effort entrusted to biologists, and to be successful, it requires the cooperation of many researchers, internationally as well as nationally.

One concern for the biological research community and the American taxpayer is whether or not such a big, regimented, resource-consuming endeavor is the most effective way to get results. Many biologists feel that such a goal-oriented, applied research project will drain funds away from basic research and actually impede progress toward our understanding of the human genome. Another issue of concern to research biologists as well as practicing scientists and society in general is where and how science and technology will meet. Where do we draw the line between getting knowledge (science) and using knowledge (technology)? Should the possible misapplication, or perceived misapplication, of knowledge limit the questions a scientist can ask and investigate? What influence does or should society have on the questions that a scientist asks, and correspondingly, how much influence do scientists have on the direction that society takes? The HGP provides an excellent backdrop against which to consider these issues.

The Psychological Perspective

Behavioral scientists have struggled since the time of Galton with a fundamental and persistent question: How much of our behavior is attributable to developmental experience and how much is programmed by our heredity? In a variety of contexts, ranging from efforts to understand psychopathology and personality to concerns about intelligence and addiction, this issue has captivated and at the same time confused both the scientist and the layperson. Historically, efforts to resolve this issue have focused on the study of twins and adopted children. The question referred to above is fundamentally unanswerable because the expression of any genotypic potential is dependent upon the environment in ways that are complex and not well understood. We human beings, quite simply, are products of both environment and heredity. If nothing else, the effort to tease apart their influence has yielded a new and growing appreciation that heredity plays a role, sometimes subtle and other times quite profound, in all aspects of human life and that no effort to understand who or how we are can be complete without substantial reference to biology and the role played by our genes in orchestrating the symphony of human behavior.

From the perspective of the behavioral sciences, decoding the human genome holds out the possibility of choosing personality characteristics, aspects of intelligence, and creativity. It also may present the potential to eliminate psychopathology or perhaps to induce it in an enemy through a virally encoded genetic infection. Soon we may have the ability to shape people biologically to fit certain socially defined roles; reminiscent of Aldous Huxley's *Brave New World*, it is equally promising and threatening. But the possibility of social engineering through genetic manipulation is predicated on the questionable assumption that heredity plays the key role in shaping or determining an individual's behavior.

The Philosophical Perspective

Philosophers are interested in two different but related aspects of the HGP. First, theoretical and philosophical questions are asked in reference to the project. Socrates' demand was for clarity, logical consistency, and coherence. Proposed views and theories had to meet the criteria for good reasoning. In Plato's dialogues, Socrates is continually questioning the acceptability of key definitions, drawing out the logical implications of various views. Similarly, since one of the practical outcomes of the HGP is to identify genetic diseases, it is important to provide as clear and unambiguous a definition of genetic disease as possible in light of the United States' troubled past regarding genetic disease and eugenics.

Second, the HGP poses a number of ethical questions grounded in a long Western tradition beginning with Socrates and Plato regarding issues such as free will and responsibility. Scientists within the HGP have consistently described it by using deterministic language. James Watson has referred to the project as the search for ultimate answers to the chemical underpinnings of human existence and added that in large measure our fate is in our genes (Anna and Elias, 1992). These assertions pique the interest of philosophers because they have a long-standing interest in determinism and reductionism.

If there is a predisposition to homosexuality, alcoholism, and depression for example, can persons be held responsible for being homosexuals, alcoholics, or depressives? There is a need to think about and to try to understand what characteristics are genetically determined as well as the roles people play in determining their own destinies.

A number of important ethical questions are raised by the project. For example, a typical topic in a bioethics course is abortion. Some philosophers argue that if a fetus is identified as having a serious genetic disease, such as Huntington's, the parents have a moral obligation to have an abortion. Dorothy Wertz (Abraham, 1989) found that while no parents would consider an abortion if genetic markers revealed a predisposition for schizophrenia, alcoholism, or moderate retardation, several said they would terminate for obesity. Another moral concern raised by the project is whether children should be tested for genetic diseases for which there is no treatment? When is it permissible to have a mass genetic screening program? Should germ line therapy be permitted? Philosophers find a very rich context for contemplating moral issues as they reflect on the implications of the project.

Course Strategies

The fundamental task for instructors is to formulate a coherent integration that allows each disciplinary perspective to be represented in the classroom discourse while weaving these disparate perspectives into a meaningful presentation. Students need to appreciate the different points of view yet grasp the underlying themes that anchor the course. To achieve these objectives, the course employs three main strategies. Each module forms the basis for a student questionnaire, a minilecture to which each of the instructors contributed, and a set of readings from assigned texts and contemporaneous sources including newspapers and magazine articles.

The Questionnaire

Class sessions begin by having students get together in small groups to complete a questionnaire on the assigned topics. The questionnaire is purposely ambiguous, designed to generate group discussion by forcing students to think about readings for a particular module. An example of a statement from a questionnaire is, "All short children should receive growth hormone injections."

Lecture and Discussion

The general session consists of two main parts: a discussion of statements on the questionnaires followed by a presentation from the instructors. For example, in considering short stature, a biological basis and mechanisms of hyposomatotrophism are first presented by a

biologist. This is followed by a discussion of the psychosocial problems associated with short stature. Finally, the issues of fairness in the allocation of medical resources are addressed.

Each of the instructors should be present at all general sessions because a successful interdisciplinary course requires the active participation of the instructors in the disciplines involved. The instructors serve as role models in the critical exchange of ideas. Just as they are expected to challenge the views of students, they also must challenge each other's views.

Supplementary Readings

Current articles from newspapers, magazines, or journals on aspects of the HGP reinforce the topicality of the course. The articles should be evaluated from the various disciplinary perspectives, and students can develop some expertise.

Selecting Resources

Finding appropriate resources for the course proved difficult, given that the course had no prerequisites and students came to the class with various interests and academic backgrounds. Therefore, the required readings could not be too technical; yet they needed to provide a solid basis for engaging in meaningful dialogue and critical evaluation of the HGP. Because so much has been and is being written about the project, the following criteria were used to select materials:

- ◆ Presence of paradigmatic examples that students could understand
- ◆ Breadth of coverage sufficient to incorporate the three disciplines represented in the course
- ◆ A clear basis in biology and genetics
- ◆ Significant personal or social impact
- ◆ Currency

An example of excellent reading is *Access to Treatment with Human Growth Hormone: Medical, Ethical, and Social Issues* (Conference Proceedings, University of Wisconsin, 1992). This work includes articles from individuals representing each of the three disciplines. The papers are intelligible to students with little background in the relevant disciplines.

Summary

The technical complexity of the HGP can be overwhelming, philosophical discourse can be difficult, and the minutiae of behavioral genetics can be confusing. Yet, course evaluations reveal that students came away from this experience with a sense that something important and worthwhile had happened in the classroom. This multidisciplinary approach to the Human Genome Project embodies the very best of the liberal arts experience because it encourages debate, it values different points of view, and it demonstrates intellectual coherence. For students and faculty interested in exploring both the scientific richness and the ethical complexity of the Human Genome Project, the multidisciplinary model is clearly worthy of consideration.

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Related Readings

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27

Genes in the Making: Human Genetics for General Education in Community Colleges

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Abstract: This paper outlines a general education course dealing with the various aspects of human genetics, including pertinent health education, moral, and ethical issues. The course is designed to serve a cross section of the college community. Topics include classical and molecular genetics and public policy issues. A framework for the course described may be obtained by contacting the author.

Relevant discipline: introductory biology

The Need for a Course in Human Genetics

During the past two decades, as a result of an aggressive campaign to conquer human diseases, especially those considered hereditary in nature, tremendous progress has been made in the science of genetics. One of the offshoots of genetic research was the establishment of the Human Genome Project in 1987. The accelerated pace of research in molecular genetics has brought a wealth of information from the Human Genome Project. With this knowledge came new career opportunities in biotechnology. Community colleges can provide their students, including those seeking biotechnology career opportunities, the fundamental knowledge required for these emergent technologies by incorporating a course covering human genetics in their general education requirements.

The Expected Outcome of the Described Course

The course described here is for students who have little or no knowledge of science, let alone molecular biology. One of the goals is to develop an appreciation of science. The interdisciplinary aspects include a history of science, with emphasis on DNA-related discoveries; health education; and moral, ethical, legal, and public policy issues. Emphasis is given to student writing of research papers and to oral presentations and discussions on selected topics in the classroom. The use of audiovisuals enhances the learning process.

Outline of Course Content

The following units encompass discussions on issues that have become the hallmark of many debates worldwide as a result of the identification of genes in human hereditary diseases and the related progression in a family or population.

Unit I: A Historical Perspective on Genetics

This unit comprises Mendelian genetics and a historical perspective, inheritance patterns observed in living systems, and human inherited diseases.

Unit II: The Progress of Genetics

This provides an overview of the simple but elegant experiments that led scientists to understand and decipher the workings of the DNA double helix. It deals with such topics as DNA replication, how genes control metabolism, mutations and their effects on proteins, and the control of gene expression in pro- and eukaryotes; these topics are intended to demystify for students the ways that genes operate in a living system. Francis Crick said: "To unscramble a complicated system, one can take it apart and characterize all the isolated bits—what they are made of, and how they work. Then one can find exactly where each part is located in the system in relation to all the other parts and how they interact with each other" (Crick, 1988).

Unit III: The Genetics Revolution of the Nineties

The tools of molecular biology include electrophoresis, recombinant DNA technology, and cloning, which gained new-found expression in the 1990s. The mid-1990s brought an improved version of the polymerase chain reaction used to amplify short segments of DNA. Following this were rapid advances in computer technology; the sequence-tagged sites (STS); content mapping; serial analysis of gene expression (SAGE); cloning systems such as cosmids, PI-based clones, and bacterial artificial chromosomes (BACs)—all of which provide plausible ways to clone DNA.

Unit IV: Societal Issues

This unit deals with the use and potential misuse of genetic information in the wake of the identification of genes of several fatal inherited disorders. Society is increasingly aware that the uncontrolled dissemination and use of genetic data entail significant risks. Health education, moral, and ethical issues; DNA and the legal system; and public policy issues are covered.

Both the Department of Energy and the National Center for Human Genome Research, a component of National Institutes of Health, have set aside a portion of their research budget to anticipate, analyze, and address the ethical, legal, and social implications (ELSI) that arise as a result of human genome research. The project planners created the NIH-DOE-ELSI Working Group, which has broad and diverse membership including genome scientists; medical geneticists; experts in law, ethics, and philosophy; and consumers to explore and

propose options for the development of sound professional and public policies related to human genome research and its applications (Hudson, et al., 1995).

Health-Education Issues

Students discuss the implications of the revolution in genetics for human health issues. One area of focus is the potential for a better understanding of disease through intensive mapping of expressed sequence tags and sampling of genomic sequence. Gene therapy is another consequence of the Human Genome Project to be considered. Many diseases and abnormalities have been successfully treated in this manner (Bordignon, et al., 1995). Students study one such disorder: Adenosine deaminase deficiency (ADA), a genetic disorder of severe combined immunodeficiency. Another avenue that shows promise is gene transfer, a procedure in which an expression cassette made up of one or more genes and the sequences controlling their expression is delivered using a vector.

Moral and Ethical Issues

When recombinant DNA technology took off a decade ago and when the first human-made oil-degrading bacteria were created in the laboratory, questions were raised concerning the patenting of life and gene therapy. There is some consensus that using somatic cell gene therapy to treat serious disease is an ethical therapeutic option. However, germ line gene therapy is still controversial and very much in an experimental stage. The major arguments against germ line gene therapy are philosophical, ethical, and theological. Students discuss these issues in relation to background information such as a recent statement from a group of nearly 200 religious leaders opposing the patenting of life (Cole-Turner, 1995).

DNA and the Legal System

One of the major concerns emanating from the discovery of genes causing various diseases in humans is the fear of discrimination in obtaining health insurance and possible employment discrimination for individuals with known predisposition to genetic diseases. Students confront these issues through discussion of the following two genetic abnormalities:

- ♦ The long QT syndrome, so called because of the distinctive diagnostic pattern on an electrocardiogram. The disease is due to an alteration in a gene on chro-

mosome 7, one of several genes that cause the QT syndrome.

- ♦ The BRCA1 gene, which confers hereditary susceptibility to breast and ovarian cancer in some families.

Students discuss the advantages and disadvantages of prior knowledge of genetic disorders from a societal point of view. Discussion revolves around the issues of preventive medicine versus the high cost of treatments and hospitalization after the disease sets in.

Public Policy Issues

Financing the Human Genome Project is one of the many public policy issues. It is estimated that the total cost of producing high-quality human sequences is likely to be less than \$1 billion of federal government funding. Some of the many other public policy issues addressed by the United States are tied to both genomic research and the use of the data it produces. Students focus on four areas of immediate interest to the public at large on the outcome of genome research: privacy, fairness, clinical applications, and professional and public education. They also consider the cultural and social influences that would help prevent stigmatization and discrimination in people's lives.

The Human Genome Project and the Future of Humankind

The unexpected advances in the Human Genome Project have prompted scientists to revisit their priorities and establish new goals. One of the key elements in the new goals is the establishment of outreach programs aimed at educating the masses about genetic research and how it affects them. Training of more personnel and technology transfer are two of the other items on the new agenda. By fine-tuning and addressing the societal issues that arise as a result of genome research, scientists hope that the future health of all citizens will be better than it is today.

Summary

Students in this course will expand their knowledge of genetics and of trends in that field. They will learn about the Human Genome Project and begin to appreciate scientific research and its ramifications beyond the confines of research laboratories. They will weigh the benefits of

genetic research against the social and moral issues of mankind and will develop skills of critical thinking and analysis while debating these challenges. The general nature of some of the topics might inculcate an interest in the minds of novices and provide impetus to those who already wish to follow the road to science. The overall outcome of such a course is to educate the community in areas that pervade our lives.

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28

Educational Catalysts and Their Implications

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Abstract: Society has little chance to understand the implications and dimensions of the genetics revolution without a more effective understanding of basic and complex principles of genetics. Mesa Community College Anthropology and Life Sciences have focused on building an innovative multimedia approach to teaching genetic principles. Students are brought closer to understanding the linkage that exists between genetics and the broader understanding of the biological and social worlds.

Relevant disciplines: genetics, psychology, introductory biology

Introduction

There is a growing awareness within both the life sciences and the social sciences that human behavior is a multifaceted interplay of biological and social factors. While genes do not directly create a person's behavior, they surely provide means by which a person will act. In social science, there is a growing effort to adjust the perspective and discuss the relationship between genetics and behavior. This involves not only engaging in new ways of examining the nature of human behavior, but also considering behavior within an evolutionary perspective. Concepts such as coevolution and social Darwinism are shaping these new perspectives (Durham, 1991). All of this can be quite overwhelming to teach and learn given the newness and complexity of the subject matter.

Students must be engaged in a learning process that is active if they are expected to comprehend the implications of this new perspective. Mesa Community College (MCC) is attempting to adopt a pedagogy that enables students to think about the implications of genetic factors.

This paper focuses on three issues: (1) where to place the focus in genetics education, (2) how to engage students in the learning process so that they will be better prepared to comprehend the exploding world of genetic information, and (3) how social science can provide a basis for understanding the implications of our knowledge of genetics.

What Should Be the Focus of Genetics Education?

We now understand that DNA is a product of evolution and that the accrual of genes builds complex organisms from simpler ones. A large portion of the public, however, does not understand many of the implications of genetic research. Yet how society interprets the countless pieces of information that we are learning about our genes affects how we understand ourselves. How educators teach this information affects how society will interpret it.

Many social scientists consider the effect of our genes on our brains, and therefore our behaviors, to be one of the most important components of the genetics revolution (Bingham and Einhorn, 1995). In a sense, human brains are created by genes and all share a common architecture (Bickerton, 1990; Calvin, 1996). These brains, however, are flexible enough for cultural variations. We all have coded patterns of activities

of brain cells and neurons that we utilize in an attempt to reconstruct the world around us. These patterns vary between individuals in ways that differentiate us. Certain things are wired (Bingham and Einhorn, 1995; Calvin, 1996), and we are only beginning to search for a "human nature."

Why do we crave salts, sweets, and fat but not fiber? Why are we jealous? Why do people of all cultures smile when they are happy and frown when they are unhappy? Why do we all share a loss of comfort in a crowded elevator just as primates do when they are crowded into enclosures? Why is the melody and slow pace of speech of a mother likely to cause babies to respond in one particular way while a normal adult speech pattern does not? Why have emotional memories brought about by fear been observed in humans, baboons, dogs, cats, fish, and fruit flies (Calvin, 1990; Savage-Rumbaugh and Lewin, 1994; Bingham and Einhorn, 1995)?

A priority within education should be to better prepare our students to understand how to consider questions such as those posed above. One of the issues that needs to be addressed is how our society perceives genetics. Our society might be more content with the simpler genetics of Gregor Mendel (Edey and Johanson, 1989). Genes contribute to what we look like physically; the idea that they may condition some of our behavior as well creates uneasiness among most people. If science finds (as it has recently) that hormones released during pregnancy in mice relate to development of mothering behaviors, this raises the implication that human mothering behavior may be genetically determined. Our society might well prefer to think that mothering is a learned, not genetic, trait.

It is safe to say that genetic research makes us uncomfortable as a society by leading us to conclusions that are difficult for many to accept (Sagan and Druyan, 1992). Many studies indicate that nearly half of all Americans would like evolution either to be taught in public schools only in a limited manner or not to be taught at all. It seems clear that the idea that we are a product of evolution causes many people to be uncomfortable. Yet, by the very nature of what we are learning about our genetic selves, we place ourselves in an evolutionary perspective. Our new understanding of genetics challenges old and accepted ways of viewing humanity.

Education must take the lead in making knowledge of genetics meaningful so that informed decisions can be made as to how this information is used. For instance, how we deal with issues concerning the ethical implica-

tions of gene therapy or the possibility of creating "designer" children depends upon how effective education is in addressing our new base of knowledge.

Engaging Students in Learning

A pedagogical shift in basic instruction techniques has occurred over the past six years in the Anthropology and Life Science Departments at MCC. This shift includes the use of a series of multimedia materials that encourage students to think about the information they are learning and apply their knowledge to various simulations. The following section provides some examples of these applications and how they relate to the genetics revolution.

Anthropology

Consistent with traditional organization of biological anthropology courses and texts, students in anthropology at MCC initially are exposed to different facets of how nature works in a Darwinian sense. The focus then shifts to a discourse on genetics with emphasis on Mendel and molecular genetics. Students should then be able to apply the concepts and terminology in a general way to an overview of the fossil record and human evolution. Students do not automatically make these connections without a measure of reinforcement and visual understanding. A series of computer-based applications is used to instill a firmer base of understanding.

The computer software draws upon the writings of such people as Stephen Jay Gould and Jared Diamond. Students encounter pandas, baseball, and the evolution of Mickey Mouse as they are presented with terminology such as *convergent evolution*, *adaptation*, and *punctuated equilibrium* in text and visual formats. Introducing terms and concepts within a highly visual environment is critical for providing a better base for understanding. Using the software, students then turn their exploration to genetics and, in a similar manner, are introduced to the molecular basis of genes and to terminology important for understanding the subject of genetics.

These introductory computer applications are points of entry for a more intensive exploration that links terms and concepts in simulated contexts. The first simulation experience enables students to become predators and asks them to kill as many frogs as they can within a specific time frame. There are four colors of frogs on the computer screen in an environment in which some blend in and others are easily seen. The students' mission is to click on as many frogs as they can. Students then calcu-

late the gene frequency change that has resulted from their predation. Then students begin a second phase of their experience; however, this time the rules by which the world works have changed—some of the frogs are poisonous, some don't taste good, and some bite back!

The frog kill experience is designed to provide students with a sense of how nature works. Students also are provided the opportunity to learn how the genetics of the frogs mirror those of the human blood system. The students are introduced to the world of Bougainville, an island between New Guinea and the Solomon Islands studied by anthropologists in the 1950s, in the last part of the simulated experience. Different villages on Bougainville have different percentages of four blood types, and students are asked to identify how many different mechanisms could lead to the results found by the anthropologists who studied these people. As with the frog simulation, natural selection is not the only influencing factor here; other forces, such as drift, sexual selection, founder effect, or gene migration, come into play. Students have to apply their understanding of each concept in order to address possible mechanisms at work.

Life Science

Two years ago, the MCC Life Science Department embarked on an endeavor similar to that in Anthropology. With the assistance of a National Science Foundation grant, a series of computer exercises was assembled to foster the process of discovery. The efforts involved a rather extensive rethinking of how to teach nonbiology majors a subject they are usually required to take as a lab science.

Students begin their biology studies with a software application called Biomes, an exploration of the natural world. They investigate the fundamental aspects of population growth and migration in the application Biopopulations. They study graphed data illustrating that population growth is not unlimited, leading them to hypothesize how populations grow, stabilize, or decline. Students are asked to consider explanations and implications of birth rates or migration.

The Implications of Our Knowledge of Genes

Since the 1800s, a powerful debate has commanded the attention of the scientific community and society itself. At the center of the discussion is the question of what really causes human behavior. Are humans prenatally

predisposed toward certain behaviors through genetics and body chemistry—"hard-wired that way at the factory"—or are postnatal social forces—culture, social class, family, religion, education, and so on—responsible for human actions? Often, it is difficult for those immersed in the physical and life sciences to recognize the significance of socialization in the behavior causation debate. The reverse can be true of those trained in the social sciences, who can downplay the influence of genes as conditioners of behavior.

No issue has centered on this difference more than the famous nature-nurture controversy. If public opinion and the amount of media coverage (which can influence public opinion) are used as criteria for how the debate is going, it would seem that, through history, the controversy has fluctuated back and forth. Before the 1800s, biological explanations dominated. Until recently the pendulum seemed to swing over toward the socialization side as observations by Ivan Pavlov, John Watson, Emile Durkheim, Max Weber, and Ashley Montagu became popular. Presently, with the emergence of the Human Genome Project in the late 1980s, we again see the pendulum swinging back toward the biological, or genetic, explanation.

Even with new-sounding titles like *Sociobiology*, *Evolutionary Psychology*, or *The New Social Darwinists* (Horgan, 1995), the dominant message remains the same—our behavior is predetermined by genetics. In the past several years the public has seen many media reports claiming the discovery of a genetic cause for mental illness, sexual orientation, alcoholism, criminality, and even couch potato behavior.

There is hope that medical breakthroughs will occur for finding genetic causes and cures for diseases from sickle-cell anemia and cancer to hemophilia and diabetes. But, outside its medical value, will it—can it—tell us everything regarding the total etiology of all human behaviors? Or, as biomedical ethicists warn, could the current trend toward genetic explanations for human behaviors create sociological and legal nightmares for society?

For example, consider the 1965 genetics study of Scottish prison inmates that led to the belief that males with an extra Y chromosome (XYY) were genetically predisposed to violent crime. Further research proved such an assumption incorrect—an estimated 96 percent of XYY males lead normal lives. But before the matter was put to rest, scientists were urging massive prenatal screenings and abortions to protect society. Other ethical ques-

tions are also being raised about the potential for a “new eugenics” movement with Hitlerian consequences emerging out of the paradigm shift to genetics-explains-everything. For example, insurance companies are suggesting the future possibility of using gene screening to deny coverage and service to people who are tested and found to have genetic defects.

In the social sciences we emphasize multicausation explanations for human behavior. We are products of both genetics and socialization. As Geoffrey Cowley remarked, “There is nothing inherently determinist about a biological perspective and nothing to be gained by pretending to live outside of nature. Biology shapes our impulses and aptitudes, but it doesn’t act alone. There is always a context” (Cowley, 1995). That context is where socialization comes in. The degree to which one’s genetic potential is ever realized is a function of the process of learning; both are absolutely essential to a normally functioning human being.

Biologist Michael Meaney of McGill University warns against arguing the primacy of genetic explanations as well: “The people in the genome project gain greatly from the misperception that if you [identify] a gene you have explained something.” In one study, Meaney separated newborn rats from their mothers for an easy 15 minutes or for a stressful six hours a day. He found that “receptors for certain brain chemicals, and the gene for the receptors, are both altered. As adults, the rats that were stressed as pups had fewer of certain receptors and so tended to overproduce stress hormones; normal rats had more receptors and were less likely to be flooded with hormones during stress. Might certain childhood experiences . . . determine whether one develops more or fewer brain receptors?” (Begley, 1996).

A chemical analogy might prove helpful in understanding the interplay of genetics and environment. One may ask a chemist, “Which is more important to ordinary table salt, the sodium or the chlorine?” Chemists would point out that the question makes no sense, for without either sodium or chlorine, we would not have salt. Sodium and chlorine are separate elements, but with respect to salt, they never exist separately. They are always in a process of continuous molecular interaction. The same seems true regarding genetics and socialization.

Conclusion

The future is one of excitement, new discoveries, new understandings, and new perspectives. It is also full of challenges for those who study human behavior. There is clearly a need to present the following:

- ◆ The linkage between genetics and social behavior
- ◆ The arguments that focus on the nature versus nurture debate
- ◆ A view that focuses on multivariate factors causing human behavior
- ◆ A challenge to students to grapple with understanding ways to view the complexity of human biology and behavior

The challenge for education is to provide the skills necessary to understand information on the genetic revolution and to apply it to daily decision making.

Clearly, one of the primary outgrowths of the focus on the Human Genome Project is to once again bring attention to human nature. The social sciences are adjusting to accommodate this change and to engage in new ways of looking at human behavior. To do otherwise is to attempt to avoid the inevitable.

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29

A Learning Community Biotechnology Curriculum

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Abstract: Accelerated advances in molecular biology have created unique opportunities for development of teaching strategies that allow for informed discussion of scientific and public policy issues arising from the genetic information explosion. This paper describes a learning community curriculum for health science majors that places the core concepts of general biology and sociology in a framework that brings out the current issues in biomedicine, biotechnology, genetic engineering, genetic screening, gene therapy, and DNA analysis.

Relevant disciplines: introductory biology, sociology

Background

Skagit Valley College is a two-year community college situated in Mt. Vernon, Washington, between Puget Sound and the Cascade Mountains. The college has instituted learning communities where two or more disciplines are combined into a single course that is team-taught. Learning communities place more emphasis on webs of knowledge and interconnectedness than on traditional presentations of separate disciplines.

A student graduating with an academic transfer degree from Skagit Valley College must take either one trivalent learning community or two bivalent learning communities. An example of a trivalent course is Darwin, Freud, and You, combining a biology, a psychology, and an English course. The learning community that is the focus of this paper, a combination of biology and sociology, is titled Living Systems in a Changing Society: Controversies and Commonalities.

Introduction

The combination of general biology and sociology was initiated by a need to provide a learning community for the two-year registered nurse program. The one described in this paper combines nursing education with the exploration of moral and ethical issues in health care delivery. The course is open to a variety of preprofessional students interested in medicine, dentistry, biology teaching, social and political science, as well as to liberal arts students.

All of these students can benefit from a course that examines the social implications of the explosion of scientific information and biotechnology. Students entering medicine, nursing, and sociological fields will encounter practical challenges as they progress in their education and practice. Liberal arts students will need to weigh political and personal decisions for themselves and future generations.

The topics chosen to demonstrate the interrelationships between the disciplines in this learning community include structural hierarchies, genetics, evolution, natural selection, nature versus nurture, Lamarckian ideas, and social Darwinism.

The course attempts to provide a factual background for the demands of a more sophisticated, encompassing level of thinking. Class discussions and seminars encourage the integration of concepts. Students are encouraged to cross the traditional borders of the disci-

plines by using critical thinking generated by data collected through application of the scientific method and appropriate statistical analysis. For this reason, the course includes the use of data tables, methods of graphing, and descriptive statistics. Some of the principal topics and major concepts that are discussed in the course include:

- ◆ The basic building blocks in the sociological and biological disciplines, from atomic structure to social institutions
- ◆ Approaches to the disciplines and the value of the scientific method
- ◆ The production and use of energy in life and society, cell metabolism, and production and reproduction
- ◆ Genetics and social engineering, including social change theories, social consequences of genetic engineering, and public policy issues surrounding animal experimentation, organ transplants, and recombinant DNA studies
- ◆ Human genetics and social development, genetic diseases, intelligence and class, perceptions based on ethnicity (racism, prejudice, and discrimination), and related public policy issues
- ◆ Evolutionary theory, including classical Darwinism, neo-Darwinism, social Darwinism, and social stratification
- ◆ Diversity of life, including the classification and characteristics of the major phyla, gender relations, gender discrimination, and sexual harassment
- ◆ Communication and the use of symbols in social relationships
- ◆ Ecosystems and the role of technology in productivity and recycling

Applications of Biotechnology

Definitions common to biology and sociology are introduced early in the learning community, and those concepts that help to unify the separate disciplines are emphasized. A central theme of the course, however, is an elaborated discussion of an operational definition for applied genetics or biotechnology. One such definition of applied biotechnology that is used is the following: the engineering of life processes with an implication of doing this for commercial ends (Yoxen, 1983).

The course reviews a number of examples of applied genetics, pointing out some immediate benefits of biotechnology. Some of the examples that are used are:

- ◆ Production of synthetic human insulin from *E. coli* or other bacteria, making this substance more readily available
- ◆ Production of interferon for the prevention of tumors—i.e., production of a molecule that “interferes” with further infection by a virus
- ◆ Production of growth hormone through bacteria or by gene transfer into *E. coli* and subsequent extraction from the bacterial culture
- ◆ Production of synthetic blood plasma as, for example, production of serum albumin protein from the *E. coli* bacterium and production of clotting factor VIII for hemophilia
- ◆ Production of monoclonal (immune system) antibodies that will attack and immobilize antigens (or foreign substances) and have implications for the vaccination process
- ◆ Production of synthetic antigens (viral fractions), a process that either produces a virus molecule that has been emptied of the genes that produce its “bad” effects or produces a structural part of a virus that is recognized by antibodies as a whole virus, both of which have implications for vaccination programs

Gene therapy in which genes are typically spliced into viruses that then enter and carry healthy genes to host cells having a defective gene or even lacking a gene altogether. Four major areas of current or imminent gene therapy activities that are highlighted in the learning community are:

- (a) Using recombinant DNA to produce hybrid genes that correct a biological error such as Parkinson’s disease, Alzheimer’s disease, cystic fibrosis, hemophilia, sickle-cell anemia, thalassemia, and Down’s syndrome
- (b) Genetic engineering of animals to boost the rate of reproduction or number of progeny or to produce offspring that are superior in some way to their parents
- (c) Other agricultural uses of gene therapy, including manipulating plant genes (protoplasts) for greater tolerance to pests, to withstand droughts,

to ripen faster, to withstand the rigors of mechanical picking (breeding plants for thick skins), to be more tolerant of salt (so it can be irrigated with seawater), to “fix” nitrogen, and to make more efficient use of sunlight

- (d) Possibility of human cloning, just as the asexual production of cloned trees or cloned rabbits or, now, cloned sheep, brings the prospect of the standardization of humanity and the possibility of losing human diversity. In a world of Ebola and AIDS viruses, a standardized humankind would be vulnerable indeed!

Although these examples do not constitute an exhaustive list, they do cover most of the main instructive areas of biotechnological applications. And all of these examples of applied biotechnology are fraught with ethical, legal, and public policy issues that are explored in the learning community. More particularly, at least four major public policy arenas are relevant for an amplified discussion in the course. The following section is a truncated version of some of the thorny issues that the learning community investigates in each of these arenas.

Applied Genetics and Public Policy Issues

The course emphasizes that most of the examples and illustrations come out of gene therapy applications, as it is these applications that we feel best underscore the dilemmas and contradictions in the relationship between biotechnology and society.

- ♦ Challenges to community traditions. What institutions are needed by society to deal effectively with biotechnical advances? Some examples of these challenges are:
 - (a) The creation of new ethical dilemmas such as organ transplants that cross racial and species boundaries
 - (b) Open womb surgery that is perceived by many as an interference with God’s will and the “divine plan”
 - (c) The bypassing of immune systems for medical treatment and the possibilities of creating exotic forms of pathogenic microorganisms by making end runs around natural defenses

- ♦ Treatment of disease through gene therapy applications. Some examples of the issues considered by the learning community are:

- (a) Privacy and confidentiality issues that include who has access to an individual’s genetic data and how long the information will be stored (Barker, 1995, and Frankel and Teich, 1994)
- (b) What people really want to know about their future health problems and how they can best be prepared for future disabilities (Duster, 1990)
- (c) Designer genes, efforts to create biological outcomes to specification and to overcome the limitations of species by splicing organisms and “fixing” traits (Yoxen, 1983; Peters, 1994; Nayar, 1996)

- ♦ Control of biotechnology and its tendency toward commercial enterprise

- (a) Whether biotechnology can serve both corporate and public interest, as in the case of cloning trees, which produces a high yield but reduces diversity and makes the tree species more vulnerable to disease and pests
- (b) The relation of biotechnology to the labor force and the attendant restructuring in production relations
- (c) Patenting of new plants or of plants having specialized traits, patenting and control of new hybrid seeds, and the chilling effect that these control issues have had on the open and democratic content of scientific investigation and public discussion

- ♦ The identification of genetic patterns and their association to social behavioral categories. Will genetic information be used simply as personal medical history or could the information be used to identify specific characteristics of a population, homosexuality, potential criminality, or high insurance or credit risks that could lead to stigmatization?

The Use and Potential for Misuse of Genetic Markers

Will the information produced by the Human Genome Project resurrect eugenics or simply provide necessary information on the value of diversity? There are four

areas that are explored around these questions in the learning community:

- ♦ Gene screening: This includes sequencing genes, identifying on which chromosomes genes are located, and linking genes to particular metabolic pathways or to particular genetic outcomes.
- ♦ As more diseases and human characteristics are linked to particular genes, the greater the basis will be for genetic screening programs. The difference between the screening programs for Tay-Sachs disease among the Jewish populations in Washington, D.C., and Baltimore areas and those for sickle-cell anemia among African Americans in California, in which schoolchildren were denied educational opportunities as a result of positive test results, underlines some of the real risks different populations may encounter in the context of racism, misogyny, anti-gay/lesbian ideology, special interests, and differential political power (Duster, 1990).
- ♦ Under what conditions should carrier screening programs be voluntary or compulsory? The learning community scrutinizes the notion that public policies need to be in place for justifying the use of screening programs, outlining safeguards to protect citizens from screening and from negative consequences accruing to individuals who are screened.
- ♦ Genetics and IQ: The learning community raises the questions: What is intelligence? How much of it is determined by genetics and is it a multifactorial phenomenon involving nongenetic dimensions? Students review *The Bell Curve* (Herrnstein and Murray, 1994) and balance what is learned there with group readings of the articles assembled in the text *The Bell Curve Wars* (Fraser, 1995). Particular attention is paid to the scientific practice contained in these texts, noticing that, for the most part, the argument around the relationship between genetics and IQ is posed in terms of the statistical manipulation of large aggregates of data and very little is focused on the molecular level of biological and genetic mechanisms.
- ♦ Historical models in the context of the social appropriation of genetics as class and race issues: Students discuss the Carrie Buck case (*Buck v. Bell* and the 1927 Supreme Court ruling on this case [Gould, 1981]) and the subsequent crafting of sterilization laws in 20 states. The Tuskegee syphilis experiments

conducted on over 400 African American males between 1932 and 1972 (Jones, 1981) provide an insight into ways in which bioethics have been used in the past. The articles assembled in the book entitled *When Medicine Went Mad* (Caplan, 1992) illustrate how genetics and biotechnology may have different impacts on women and minorities as well as how advances in biotechnology may be perceived quite differently by populations that have historically been discriminated against.

- ♦ Collection of blood samples from indigenous peoples: This brings up the novel developments surrounding the collection of blood samples from indigenous peoples in order to identify “exotic” DNA code sequences that could be of therapeutic use. Students discuss the rationale for this practice, “for the greater good of all humankind,” in light of questions such as: What is the human good here? Who is determining it? and In the worldwide collection of blood samples of isolated villagers, what constitutes informed consent?

Challenges and Dilemmas of Biotechnology

The emergence of DNA sequencing technology has produced a variety of applications that affect the general public. Nearly everyone now accepts DNA fingerprinting as a scientifically valid tool in the identification of genetically unique individuals. Many ethical, social, and legal questions have been raised, however, by the Human Genome Project (HGP), and few of them have been answered. These provide a fertile field for class discussion. Some of the topics and related questions are:

- ♦ The privacy and confidentiality of personal genetic codes, where and for how long will this information be stored
- ♦ The social implications of using genetic information in electing public officials, hiring teachers, or screening students for specialty schools
- ♦ Use of hereditary material in choosing a mate
- ♦ Counseling individuals about whether to choose to learn about their own genetic information and how to deal with that knowledge once it is obtained
- ♦ The belief of some that the goal of biotechnology is to provide an opportunity for eternal life (Rifkin,

1983), while more conventional authorities believe it should provide for treatment of diseases, replacement of dysfunctional organs, and relief from suffering (Kimbrell, 1993)

- ♦ The improved ability to conceive children and manipulate characteristics of those children
- ♦ The economic implications of the findings of the HGP and the public and private funds that have been spent on research and development
- ♦ The ethical dilemmas caused by the care and disposal of medical wastes and products created by bio-engineering and the fear of loosing an uncontrollable and dangerous bioengineered monster on our planet
- ♦ The creation of genetic hybrids that allow the decontextualizing of functions with the associated possibility for restructuring modern industry
- ♦ The implications of the biotechnical for new sources of energy and, consequently, for the merger of energy industries and agriculture (Yoxen, 1983)

Teaching Methods and Assessment

The learning community utilizes several group processes, including seminars, class discussions, and peer-evaluated exercises. Seminar groups are assigned articles to read and discuss in small groups. Individual group members prepared summaries of the articles with particular attention to the identification of possible social concerns.

Students share their comments and ideas in the small group settings with the aim of making a comprehensive listing representing that group's work. Each group then reports to the class as a whole for further discussion. These discussions sometimes lead to spirited debates, and connections are commonly made to earlier seminars. The faculty's role as facilitators is to constantly encourage recognition of linkages between biology and sociology and to maintain accuracy in the interpretation of facts taken from the articles.

Seminars are planned to allow the students to explore concepts related to the course outline and to provide more access to outside materials such as books, articles, and personal interviews and to allow students to probe not only their own positions but also to interact with others who may have differing perceptions. These forums help to identify the limitations of any individual position and offer the opportunity for critical thinking,

questioning of assumptions, identifying of underlying values, and recognizing the pitfalls of generalization.

Lecture presentations and bibliographies are presented from both fields, forming a common conceptual background for class discussions. Videos are used to illustrate complex processes like cellular metabolism, gene action, and protein synthesis. In addition to lecture and group work, each student is required to take a two-hour biology lab each week of the 12-week course. Laboratory experiences include:

- ♦ Manipulation of chemical structures and reactions
- ♦ Experiments with digestion and metabolism
- ♦ Solving Mendelian and non-Mendelian genetics problems
- ♦ Comparison of evolutionary relationships among several animal phyla
- ♦ An overview of diversity among living organisms

Student "opinionnaires" collected at the end of the quarter reveal that students felt they benefited from the integration of biological and sociological concepts and group discussions. They valued the diverse information sources and felt increased confidence in their ability to engage in public policy discussions related to genetic research.

Preparing for the Future

If students are informed about a topic such as biotechnology and are allowed to discuss and debate these issues freely, the democratic process might be enhanced greatly and students could approach their lives better able to come to grips with decisions about procreation and disease.

In his discussion of the human blueprint, Robert Shapiro (1982) quotes an editorial from the *New York Times*:

"Deliberate manipulation of the human germline will constitute a watershed of history, perhaps even in evolution. It should not be crossed surreptitiously, or before a full debate has allowed the public to reach an informed understanding of where scientists are leading. The remaking of man is worth a little discussion."

This course is but a small testament to that discussion.

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30

An Interdisciplinary Honors Course Explores the Scientific, Ethical, and Historical Aspects of Genetics

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Abstract: Learning communities link courses from disparate disciplines around common themes, allowing participants a greater level of interaction and more integrated knowledge of the subject material. One learning cluster linking biology, religion, European history, and an integrated study of genetics and the Human Genome Project provides an effective forum for students to make connections. Information is provided about learning communities, augmenting traditional classroom activities, and resources exploring genetics and the human genome from a variety of perspectives.

Relevant disciplines: introductory biology, ethics, sociology

Introduction

Community colleges are becoming increasingly responsible for providing the general education requirements undertaken in the first two years of a college experience. For many nonscience majors, the only postsecondary science experience may come at a community college. Student attitudes toward the sciences may vary, but the feelings of many may be summarized by the response of a Kirkwood Community College honor student who, when asked to describe his reaction to previous science courses, said, "I did not like or enjoy structured science while in high school. These courses soured my view of science and scientists." For faculty faced with these attitudes, the challenges of engaging students in scientific thought and practice that will last beyond their enrollment in community college science courses might seem overwhelming.

Interdisciplinary Approaches to Science Education

Interdisciplinary coursework may improve science education in general and education for liberal arts nonscience majors in particular. Diane M. Bunce, the educator named by the Society for College Science Teachers as the outstanding undergraduate science teacher for 1995, suggests that we must allow nonscience majors to use the skills developed in other disciplines, we must make connections for these students to real world issues, and we must teach science the way students learn. Interdisciplinary studies may be especially appropriate for treatment of topics like genetics, which cross subject matter boundaries and may be approached from biological, ethical, historical, and sociological perspectives.

Theme Courses

Many of the interdisciplinary treatments that include a science component and that are reported in the *Journal of College Science Teaching* involve single courses organized around a central theme. AIDS served as the focus of a course whose faculty included a historian, a psychologist, and a cell biologist (Sommers, 1989), and of a course taught by faculty from the Medical Technology Program; Biology, English, and Communications departments; and a member of the local public health department (Aliosi, 1990–91). Other theme courses link topics and faculty from biology, chemistry, political science, psychology, and philosophy (Malachowski, 1990),

or computer science, marine geology, and literature (Pinet, 1990). Theme courses might be an answer to meeting nonmajors' needs, but they present problems with respect to faculty load and course transferability.

Defining the Learning Community

The learning community may be more practical in the community college environment than theme courses. The term "learning community" is used to describe a variety of approaches for linking courses around a common theme or question. The goal of this educational reform effort is to allow for more interaction among students and between students and faculty, and to provide an opportunity for deeper understanding of the material they are learning by exploring it from a variety of different perspectives. Learning communities differ from theme courses described earlier; rather than multiple instructors teaching a single course, they involve multiple instructors and multiple courses. Participation in a community may constitute a significant part, if not all, of a student's semester course load.

As described in *Learning Communities: Creating Connections among Students, Faculty, and Disciplines* (Gabelnick, et. al., 1990), there are five generally accepted learning community models:

1. *Linked or paired courses* in which syllabi and assignments for two or more courses are coordinated.
2. *Interest groups* create small student communities; a peer adviser serves as a resource for a student cohort enrolled in three or more courses.
3. *Learning clusters* link three or four courses together by a common theme and students enroll in all courses.
4. *Federated learning communities* are similar to learning clusters, but students also participate in a seminar linking the three courses.
5. *Coordinated studies* is characterized by team teaching and block scheduling.

Learning Communities at Kirkwood Community College

The learning community concept allowed groups of faculty at Kirkwood to link disparate disciplines in order to provide students with an integrated view of the topics they address.

The Honors Program

Kirkwood became an active participant in the learning community movement with the revamping of its Honors Program in the early 1990s. A group of faculty and administrators selected four themes to be used in establishing honors clusters. One cluster, "The Discovery of Being Human," included a significant genetics component, a study of religions of the West, the Age of Nationalism in Europe, and biology for nonmajors.

Administrative Support

At this point, many of the participants were excited about the idea of linked courses but lacked knowledge about how to plan an effective cluster. Administrative support helped fill this void in a number of ways. Selected faculty were sent to a Learning Communities Workshop at Seattle Central Community College for further training in the learning communities concept. A departmental dean was assigned to each honors cluster to serve as facilitator and to handle the logistics, including scheduling, course promotion, arrangements for rooms, speakers, trips, transportation, and library privileges.

"The Discovery of Being Human" Cluster

The courses in this cluster addressed interrelated approaches to understanding what it means to be human; humans' ability to endure and survive; human biological, social, religious, and political organization; and selected human attributes. These human attributes included the use of language to bind time, ability to manipulate the environment, genius and creativity, capacity for good and evil, and the development and application of technology.

Course Integration and Scheduling

Courses were designed to meet transfer and core general education requirements. The courses in the cluster had three points of convergence: scientific, historical, and religious approaches to acquiring knowledge; evolution; and genetics and sociobiology. Courses were scheduled to allow for extended discussion, showing of full-length films, guest lectures, and field trips.

Texts and Resources

The same texts that were chosen for nonclustered course sections were used, and faculty augmented them with

interdisciplinary readings. Those that have selections with specific application to the study of genetics may be found in Supplementary Resources below.

Interdisciplinary Classroom Activities and Assignments

Interdisciplinary assignments are part of the evaluation process of all of the course components. In order to clarify course content and connections, students were required to keep a journal throughout the semester. Students reviewed their journals at the end of the semester and selected examples of their best work to expand into a capstone essay, which contributed 10 percent of their grade in each course.

The University of Iowa, located less than a half hour from Kirkwood, provided a variety of enrichment activities in which cluster members participated. Students and faculty visited the university library, toured a molecular genetics research laboratory, and had a seminar with the laboratory investigator. They also visited the University Hospital's bone marrow transplant unit, where the physician in charge addressed issues related to the genetics involved in the transplant selection process. Students discussed procedures undertaken during the transplant, as well as the costs, benefits, and ethical considerations of transplanting human organs. Cluster students also attended lectures at the university featuring noted speakers, including James Watson.

Addressing Genetics in "The Discovery of Being Human"

The biology component of the cluster was designed as a nonmajors survey-type course. Molecular genetics was covered during weeks 1 and 2 and included the structure of DNA and RNA, protein synthesis, and cell division. Mendelian and human genetics and the Human Genome Project were addressed during weeks 4 and 5, respectively. The Microorganisms laboratory exercise in week 7 involved DNA transformation of *E. coli*. The links between genetics, behavior, and language were explored during weeks 13 and 14. "The Return of Eugenics" (Neuhaus, 1988) and possible applications of new genetic technologies were discussed during week 14. Meanwhile, the history, societal impact, and religious and ethical aspects of genetics and new technologies were being further explored in the religion and history components of the cluster.

Conclusion

Learning communities may provide the knowledge and interdisciplinary perspectives to address the changes that surely will be a part of the future. As the community college takes on an increasingly critical role in preparing liberal arts undergraduate students in the sciences in general and in biology and genetics in particular, educational strategies that encourage students to see these topics as connected to all aspects of their lives will be important.

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- Thomas, L. (1974). *The lives of a cell*. New York: Bantam.
- White, F. D. (1989). *Science and the human spirit*. Belmont, Calif.: Wadsworth.

Audiovisuals

- Ascent of man series. (1974). *Generation upon generation*.
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Additional Readings

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- Finley, N. J. (1990). Meeting expectations by making new connections: Curriculum reform at Seattle Central. *Educational Record*, 71 (Fall), 50–53.
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- Ruse, M. (1989). *Philosophy of biology*. New York: Macmillan.
- Vona-Davis, L., and Sherwood, L. (1996). *Current perspectives in human physiology: Selected readings*. Minneapolis: West.

Internet Sites

- vflylab.calstatela.edu/edesktop/VirtApps/VflyLab/.IntroVflylab.html. Allows for design, simulation, and analysis of experimental crosses of *Drosophila*.
- www.er.doe.gov/production/oher/hug_top.html. A Department of Energy Genome Project site.
- www.gene.com/ae. Although aimed at high school teachers, Access Excellence provides links to seminars, interviews, college courses, and a variety of other biological and biotechnological resources.
- www.lifesci.ucla.edu/repository/microbio&molecGenet. Can access "Dr. Don Nierlich's list of Scientific Resources and Databases."
- www-ls.lanl.gov/HGhotlist.html. Provides the Human Genome's most used links.
- www.netspace.org/MendelWeb. An educational genetics program that provides access to Mendel's original papers (German and English versions), glossaries, tutorials, pictures, a virtual classroom for online discussion, and a variety of other genetics-related resources.
- www.ohiou.edu/ictto/biotech.html. Launching pad for biotechnology resources on the World Wide Web.
- www.ornl.gov/TechResources/Human_Genome/home.html. Another Department of Energy home page for the Human Genome Project.

Appendix 1

Conference Program

The Genetics Revolution: A Catalyst for Education and Public Policy

**A conference highlighting the latest research in
genetics and the related ethical, philosophical,
and public policy issues from the perspective
of the community college.**

Made possible by a grant from the
Exxon Education Foundation.

Dallas, Texas, March 21–23, 1996

Conference Sponsors:

North Lake College
Dallas County Community College District
Exxon Education Foundation
American Association of Community Colleges
The League for Innovation

North Lake College President:

James F. Horton Jr.

Conference Director:

Marilyn Elaine Mays

* Indicates Exxon Education Foundation Innovation
Award-winning papers included in the monograph.

Thursday, March 21

8:30 AM—9:45 AM

Keynote address: “*The Impact of Genome Research*”

Speaker:

J. Craig Venter, Ph.D., president and director of the Institute for Genomic Research (TIGR). A strategy developed by Venter has accelerated the pace of gene discovery a thousandfold over previously used methods. As reported by Venter in May 1995 to the American Society for Microbiology, TIGR scientists were the first to determine successfully the order of the DNA in the entire genome of a free-living organism, the bacterium *Haemophilus influenzae*. In May 1995, *Business Week* highlighted his recent successes in its cover article. He has also been featured in *Science*, *Fortune*, *People*, and *Discover*.

10:00 AM—11:50 AM

Invited Address: “*The Human Genome Project and the Genetics Revolution*”

Speaker:

Glen A. Evans, M.D., Ph.D., Director of the Genome Science and Technology Center, University of Texas Southwestern Medical Center at Dallas, and coauthor of more than 145 articles on biocomputing and human genetics.

Invited Address: “*Automation, Instrumentation, and Software for Rapid Analysis of the Human Genome*”

Speaker:

Harold (Skip) Garner, Ph.D., Associate Director of the Genome Science and Technology Center, University of Texas-Southwestern Medical Center at Dallas. Garner has developed advanced instrumentation, robotics, and computer software for biological sample handling and genetic analysis.

12:00 PM—1:30 PM

Luncheon and presentation of Exxon Education Foundation Awards

Luncheon Address: “*The Human Genome: Is It More Than We Want to Know?*”

Speaker:

Michael S. Brown, M.D., Nobel laureate, University of Texas Southwestern Medical Center at Dallas; recipient with Joseph Goldstein of the Nobel Prize in Medicine or Physiology, 1985, and the National Medal of Science, 1986, for their research in cholesterol metabolism, making possible the creation of drugs to lower cholesterol.

Presentation of Awards:

James F. Horton Jr., President, North Lake College

Edward Ahnert, President, Exxon Education Foundation

2:00 PM—4:00 PM

Panel Discussion

The transcript of this panel discussion appears in *Issues in Science and Technology* (Fall 1996) under the title “*Roundtable: The Politics of Genetic Testing*.”

Panel Moderator:

Kevin Finneran, Editor in Chief, *Issues in Science and Technology*, a publication of the National Academy of Science, the National Academy of Engineering, the Institute of Medicine, and the Cecil and Ida Green Center for the Study of Science and Society.

Panel Members:

R. Alta Charo, J.D., Associate Professor of Law and Medical Ethics at the University of Wisconsin Schools of Law and Medicine and Legal Analyst for the Biological Applications Program of the Congressional Office of Technology Assessment.

Robert Mullan Cook-Deegan, M.D., Senior Program Officer at the National Academy of Sciences. He has played a key role in investigating the political, social, and ethical issues related to genetics research and is the author of *The Gene Wars: Science, Politics and The Human Genome*.

Rebecca S. Eisenberg, J.D., Professor of Law at the University of Michigan Law School, a member of the Working Group of Ethical, Legal, and Social

Implications of the Human Genome Project, and an expert on intellectual property issues in research science.

Gail Geller, Sc.D., Assistant Professor at the Johns Hopkins University School of Medicine, a bioethicist and behavioral scientist on a multidisciplinary research team investigating the ethical and psychosocial implications of genetic testing.

"The Ethical and Legal Implications of Human Genome Research" is a lively and wide-ranging introduction to the decisions that we as a society will face as our knowledge expands. The goal of the session will be to demonstrate the importance of bringing all of these disciplines to bear on the numerous ethical, legal, and scientific issues raised by human genome research. Topics will include genetic testing of fetuses, patenting of genetic information, the danger of eugenics, commercial uses of genetic information, protection of the privacy of individual genetic information, and restrictions on research.

7:00 PM—8:30 PM

Readers Theater with Discussion

** The Twilight of the Golds: A Paradigm of Ethical Considerations in the Genetics Revolution.*

If your parents had known many of your traits beforehand, would you have been born? One family wrestles with this mythic question in Jon Tolins' Broadway play *The Twilight of the Golds*. Set in the near future, the play revolves around a young married couple, the wife's brother, and her parents as all are forced to confront, each in his own way, what might happen when mankind seizes the ability to edit the human race. (An edited version of this play was taped specifically for presentation at this conference.) The director will moderate comments from a panel and then open the discussion to the audience.

Director:

Landon Coleman, DeKalb College, Clarkston, Ga.

Panel Members:

Jean Armitage, Alice Butler, John Mosely, Joan Weston

Friday, March 22

8:30 AM—9:30 AM

Invited speaker:

The Role of Information Technology in Health Care

Speaker:

Thomas Anderson, Past President, FoxMeyer Health Corporation

9:45 AM—11:35 AM

Paper Sessions

** Educating the Educators: Genetics Revolution in the Community College Setting*

Juville G. Dario-Becker, Central Virginia Community College, Lynchburg, Va.

** Educational Catalysts and Implications*

Richard Effland, Mesa Community College, Mesa, Ariz.

** The Integration of Genetic Knowledge into Nursing Education at the Community College Level*

Felissa L. Cohen, Southern Illinois University at Edwardsville, Edwardsville, Ill.

** Genes in the Making: A Closer Look at Human Genetics: A General Education Course in Community Colleges*

Ram Nayar, Daytona Beach Community College, Daytona Beach, Fla.

Agents of Change

Wendie Johnston, Pasadena City College, Pasadena, Calif.

** Teaching Biotechnology Concepts and Skills in the Laboratory*

Phil Shelp, Karen Bentz, Sarah Hutchings, Marynell Kaufman, Fredella Wortham
Brookhaven College, Farmers Branch, Tex.

** Growing a Community College Biotechnology Program through Collaborative Partnerships*

Elaine A. Johnson, City College of San Francisco, San Francisco, Calif.

*** Field of Dreams: Build It and They Will Come**
Charissa Urbano, Delta College, University Center, Mich.

*** Biotechnology at William Paterson College: Programs for Secondary and Undergraduate Students**
Miryam Wahrman, Robert H. Chesney, Jane R. Voss, Jean M. Werth, William Paterson College, Wayne, N.J.

*** An Interdisciplinary Approach to Genetics in a Biotechnology Program**
Barry Werner, Mariluci Bladon, Julien Farland, Mary Lee Underhill, Middlesex Community College, Bedford, Mass.

*** A Combination of Laboratories in Biotechnology Demonstrating the General Approach of the Human Genome Project**
Joan McCoy-Messer, Jones County Junior College, Ellisville, Miss.

*** A DNA Fingerprinting Exercise for Any Type of Class**
Sandra Porter, Seattle Central Community College, Seattle, Wash.

A Plan to Teach Genetics across the Curriculum
Noni Bohonak, University of South Carolina-Lancaster, Lancaster, S.C.

*** A Learning Community Curriculum: Ethical, Public Policy, and Societal Issues Surrounding the Use of Advanced Biotechnologies**
James Monroe, David Muga, Skagit Valley College, Mt. Vernon, Wash.

Thin Is In: The Ethical Implications Associated with the Discovery of the Mouse Obese Gene
Dana Lossner, Community College of Denver, Denver, Colo.

*** An Interdisciplinary Honors Course Explores the Scientific, Ethical, and Historical Aspects of Genetics**
Johanna Kruckeberg, Kirkwood Community College, Cedar Rapids, Iowa

*** Chromosomes: Crucial Road Maps for Molecular Genetic Studies**
D. Charles Dailey, Sierra College, Rocklin, Calif.

*** The Genetics Revolution: A Sense of Ownership**
Robert Badra, Kalamazoo Valley Community College, Texas Township Campus, Kalamazoo, Mich.

1:30 PM—3:00 PM

General Session

Invited Speakers:
Using DNA Today to Plan for Tomorrow
Arthur Eisenberg, University of North Texas
Robert Ricciardi, University of Pennsylvania

3:15 PM—4:45 PM

National Science Foundation Workshop
Funding Opportunities for Undergraduate Education
Bettye Blakney-Lawrence, National Science Foundation
Paul Rodriguez, University of Texas at San Antonio

Saturday, March 23

8:30 AM—9:30 AM

Invited Speaker:
Genetic Counseling: Applications of New Genome Technology
Debra Collins, University of Kansas Medical Center

9:45 AM—11:35 AM

Paper Sessions

*** Incorporation of the Human Genome Project into a Human Genetics Course Designed for Students in the Allied Health Professions**
Kim Finer, Kent State University-Stark Campus, Canton, Ohio

Genetics: A Unifying Thread
Ric Matthews, Miramar College, San Diego, Calif.

*** A Laboratory Approach to Molecular Genetics as an Adjunct to a General Biology Sequence and Clinical Chemistry Course**
Thomas P. Arnold, Nancy York, Darton College, Albany, Ga.

*** Instilling Job Literacy for Current and Upcoming Biotechnology Occupations**
Brian R. Shmaefsky, Kingwood College, Kingwood, Tex.

A Review of the Genetics of Sexual Orientation and Public Policies

Susan P. Speece, Fresno City College, Fresno, Calif.

*** The Third Genie**

Allen Hunt, Elizabethtown Community College, Elizabethtown, Ky.

*** Multimedia Approaches to DNA Teaching**

Adriana Cobo-Frenkel, Richland College, Dallas, Tex.

*** Bioethics in the Classroom**

Kerri L. Armstrong, Community College of Philadelphia, Philadelphia, Pa.

*** Transgenic Crops: New DNA in Your Food**

Paul Mangum, Midland College, Midland, Tex.

*** David's Dance: Historical Responses to Genetic Knowledge**

Warren Yarbrough, Mary Pittman, Orangeburg-Calhoun Technical College, Orangeburg, S.C.

*** A Multidisciplinary Approach to the Human Genome Project**

Bob Bermant, John Knight, University of Wisconsin-Waukesha, Waukesha, Wis.

*** Privacy and Medical Genetics Issues: Is There a Duty to Disclose to Family Members?**

Karen Gottlieb, BioLaw, Nederland, Colo.

BioEnglish and Bioethics: Splicing Together the Sciences and Humanities

Martha Newsome, Douglas S. Boyd, Tomball College, Houston, Tex.

Teaching Beginning Science Students the Chemical Composition of DNA

B. Kaye Walter, Kansas City Kansas Community College, Kansas City, Kan.

*** Human Genetics**

Joyce M. Greene, Community College of Philadelphia, Philadelphia, Pa.

*** An Applied Biotechnology Capstone Course: Melding the Resources of the Community College and Industry**

Dave Singer, San Diego City College, San Diego, Calif.

*** Discovering Genetics through Active Participation in the Laboratory and Field Trips**

Barbara McCormick, Daley College, Chicago, Ill.

Genetics Education: A Model for Faculty Development in Community Colleges

Lida Criner, Arkansas State University, Mountain Home, Ark.

1:30 PM—3:20 PM

Working Groups

Working groups in (1) Biotechnology, (2) Basic Science, and (3) Social Issues, Public Policy, and Ethics will meet to discuss major themes of the conference presentations, form plans of action for integrating aspects of the genetics revolution into their curricula, and develop strategies for networking in support of mutual efforts. This will afford opportunities for participants to explore possibilities of developing consortia for the purpose of exchanging ideas and pursuing funding for joint projects.

Appendix 2

Directory of Exxon Education Foundation Innovation Award Winners

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Index

A

accountability, of biotechnology program, 115

adenosine deaminase deficiency, 135

administrative support, 149

Advanced Placement Course Description in Biology (CEEB), 124

agriculture, genetic engineering and, 44–45, 57–60

alleles, 70

allied health fields, and study of Human Genome Project, 65–68

American Medical Association, 13

anthropology, 138–39

archetypes, Jungian, 34

assessment: of course, 105; of learning community, 146; of students, 119–20. *See also evaluation*

B

Bacillus subtilis, sequencing of, 2

Bacon, Francis, quoted, 5

behavior, human, 72, 137–40

Berdyayev, Nikolai, *Slavery and Freedom*, 18

bioethics, in classroom, 30–32. *See also ethical issues*

bioindustry, 7–8, 75–76, 112–14; and biotechnology curriculum, 103–6, 108, 112–21. *See also biotechnology; career opportunities*

Biological Science Curriculum Study, 30

biology, introductory, 130, 134–36, 142–46; and DNA technology, 73–76; human genetics in, 77–81; laboratory exercises for, 88–93; multimedia approach to, 82–84; role of field trips in, 85–87; teaching of, 30–32. *See also curriculum*

biotechnology: applied, 143–44; and bioindustry, 7–8; career opportunities in, 48–49, 91, 93, 103, 108–13, 120; and environment, 9, 59–60, 75–76; and ethics of the unknown, 5–10; and food, 57–60; laboratory exercises for, 88–90; public awareness of, 52. *See also bioindustry; curriculum, biotechnology; DNA technology*

biotechnology programs, 117–24; and collaborative partnerships, 112–16; future of, 124; interdisciplinary, 103–6

Blumberg, Baruch, 18

Bougainville Island, 139

Bunce, Diane M., 148

C

Calgene, Inc., Flavr Savr™ tomato, 52, 58

California Supreme Court, 9; *Tarasoff v. Regents of the University of California*, 14–15

career opportunities, 48–49, 91, 93, 103, 108–13, 120

Carl D. Perkins Vocational and Applied Technology Act (1990), 113, 118

case studies, classroom use of, 31–32, 105–6

catalysts, educational, 137–40

cell theory, 41

centromeres, 53

Christianity, history of, 19–20

chromosome analysis, of fetus, 80

chromosomes, 42, 51–55; artificial, 54; banding of, 42, 53; mapping of, 42, 53; painting of, 54; primate, 55; structure and function of, 51–55; surgery of, 54; X, 54–55; Y, 139–40

Churchland, Patricia Smith, quoted, 20

City College of San Francisco, 112–16

classroom instruction: genetic fingerprinting exercise for, 94–100; for genetics program, 48–50, 65–68, 77–81, 104–6, 146, 150; laboratory exercises and, 73–76; multimedia approach to, 82–84; for nursing, 69–72; use of case studies in, 31–32, 105–6; use of pedigree problems in, 31–32. *See also discussion, classroom; field trips; laboratory exercises*

clinical applications, 46–47

codon, 44, 74

College Entrance Examination Board, *Advanced Placement Course Description in Biology*, 124

community colleges, role in genetics revolution, 26–29, 48–50, 57–58, 60

conferences, national, 114

confidentiality, patients' right of, 13

conservation, models for, 7

consumer concerns, and transgenic crops, 60

Contra Costa College, 117–18

control: of biotechnology, 144; of genetic research, 27–28

coordinator, role of, 118–20

“coordinator’s corner,” 119

Correns, Carl, 42

course integration, 149

court decisions, 9, 14–15

courtship displays, 33–35

Cowley, Geoffrey, quoted, 140

Crick, Francis, 42, 52, 73; quoted, 135

culture, human, as genetic product, 33–37

curriculum: biology, 30–32, 49, 134–36; nursing, 69–72; pre-biotechnology, 49

curriculum, biotechnology, 108–11, 142–46; bioindustry and, 112–16; Biotechnology Instrumentation course, 117–21; Briefing in Genetic Engineering course, 113; design of, 114–15; Economics and Management course, 105–6; Introduction to Biomedical Ethics course, 105; Living Systems in a Changing Society learning community, 142–46; Methods of Biotechnology course, 104

curriculum development, for biotechnology program, 104

cybernetics, 7

cytogenetics, 41–42

D

Daley College (Chicago), 85–87

Darton College (Florida), 91–93

DeKalb College (Georgia), 23–25

Delta College (Michigan), 48–50

“Developing Biological Literacy” (BSCS), 30

De Vries, Hugo, 42

diaries, student, 85, 150

disclosure of genetic information, 11–17. *See also* privacy

discrimination, genetic, in health care coverage, 65, 135

discussion, classroom, 86–87, 104, 132–33, 135–36, 145–46

discussion, panel, 25

disease: genetic components of, 70–72; and “neutraceuticals,” 59. *See also* genetic diseases

diversity, crop, 60

DNA (deoxyribonucleic acid), 42–45; cloning of, 123; features of, 95; genome sequencing of, 1–2; isolation of, 89, 123; as macromolecule, 93; manipulation of, 93; microsatellite, 53; mitochondrial, 52; purification of, 74; puzzle model of, 73; replication of, 43, 73; sequencing of, 46; structure and function of, 52, 73–74

DNA teaching, multimedia approach to, 82–84

DNA technology, 44–45; laboratory exercises for, 73–76

drug therapy, genes and, 59, 71

duty to disclose genetic information, 14–15

Dwelling Place for Wisdom (Panikkar), 22

E

economy, U.S., and biotechnology, 8

education: bioethics, 30–32; focus of, 137–38; general, 134–36; interdisciplinary approaches to, 148–49; public, 47, 50, 58, 60, 124; science, 148–49. *See also* classroom instruction

environmental concerns, 9, 59–60, 75–76

enzyme assays, 92

equipment: for biotechnology program, 89–90, 110, 113, 119–20; for DNA technology course, 76; for mobile laboratory, 123; for molecular genetics course, 91–93

Escherichia coli, sequencing of, 2

EST (expressed sequence tag) approach, 1

ethical issues: of biotechnology, 5–10, 145–46; dramatization of, 23–25; of gene therapy, 135; of genetic disease, 81; of genetic information disclosure, 11–17; of genetics revolution, 23–25; of Human Genome Project, 46–47, 130–32

ethical relativism, 131

ethics: courses in, 105; of the unknown, 5–10. *See also* bioethics

eugenics, 8–9

eugenics, new, 140

evaluation: instructors’ self-, 120; of programs, 110–11, 115; of students, 110–11. *See also* assessment

F

faculty, and multidisciplinary approach, 130. *See also* classroom instruction; teachers, high school

fairness, as ethical issue, 46

families: and disclosure of genetic information, 11–17; and genetic counseling, 31–32; as nursing focus, 72. *See also* pedigree

Federal Bureau of Investigation, 100

Ferris State University (Michigan), 49

field trips, role of, 49–50, 85–87, 119, 150

Fire in the Mind (Johnson), 20

Fletcher, John, 13–16

Florida Supreme Court, *Pate v. Threlkel*, 14–15

foregrounding, bioindustry and, 7–8

forensic science. See genetic fingerprinting

Francouer, Robert, *Utopian Motherhood*, 20–21

fruit flies, 51–52

G

Galton, Francis, 9

Gates, Bill, *Road Ahead*, 21–22

gel electrophoresis, 74, 89, 92, 123

gender, genes and, 54–55

gene banks, 7

genes: cloning of, 75–76; defined, 44; identification, 46; mapping of, 46, 53, 75. *See also* DNA (deoxyribonucleic acid); genetic diseases

gene therapy, 45, 135, 143–44; germ line, 81, 135; somatic cell, 81, 135; use in classroom, 66. *See also* genetic diseases

genetically modified organisms (GMOs), 9

genetic code, 44, 73–74

genetic counseling, 31–32, 48, 80–81

genetic diseases, 43, 53, 135; categories of, 70; examples of, 77–81; families and, 12–13; Human Genome Project and, 46, 75; list of, 78; use in classroom, 65–66. *See also* disease, genetic components; gene therapy

genetic engineering, 8, 44–45, 75–76; agriculture and, 57–60

Genetic Engineering News, 8, 67

genetic fingerprinting, 45, 145; classroom use of, 74, 94–100; potential for error, 100; techniques of, 95

geneticists, medical, 15–16

genetic knowledge, historical responses to, 33–37

genetic legislation, classroom use of, 66. *See also* law

genetics: applied, 143–44; history of, 41–45; molecular, 42–44; public perception of, 138; rationale for studying, 49

Genetics, Inc., 9

genetic screening, 46, 86, 139–40, 144–45; nurses and, 71

genetics programs: community colleges and, 48–50; Human

Genome Project and, 65–68

genetic testing, 46, 94–95; use in classroom, 66

gene transfer, 135

Gilder, George, *Microcosm*, 57

GMOs. *See* genetically modified organisms (GMOs)

Great Chain of Being, 36

H

Hackley, Lloyd V., 108

Haemophilus influenzae, sequencing of, 1

Haught, John F., *Science and Religion*, 20

Hawking, Stephen, 8

health insurance, and genetic information, 66

hierarchies, human, as result of genetic knowledge, 33, 35–37

high schools, and biotechnology program, 122–24. *See also* teachers, high school

homosexuality, 23–25

honors program, 149

Human Genome News, 67

Human Genome Organization, 45

Human Genome Project, 1–2, 9, 32, 41, 45–47, 55, 145–46; biological perspective on, 131; classroom use of, 65–68; course objectives for, 130; and creation of human hierarchies, 36–37; ELSI (ethical, legal, and social implications), 46, 66, 72, 75, 135; and future of humankind, 136; general education course on, 134–36; laboratory exercises concerning, 88–90; multidisciplinary approach to, 129–33; personal responses to, 131; philosophical perspective on, 132; psychological perspective on, 131–32; study resources for, 67

Huntington's disease, 79–81. *See also* genetic diseases

I

immunodiffusion, 123

incest taboos, 34–35

independent assortment, genetic law of, 42

indigenous peoples, collection of blood samples from, 145

Institute for Genomic Research, 1

instructional support services, 115

instructors, self-evaluation by, 120

insulin, synthetic, 45, 76

intellectual property rights, 9–10

intelligence, genetics and, 145

International Society of Nurses in Genetics, 72

Internet, 114

internships, bioindustry, 117

interviews, classroom use of, 106

J

Jeffries, Alec, 45

job literacy, for biotechnology careers, 108–11

John Paul II, Pope, quoted, 19

Johnson, George, *Fire in the Mind*, 20

John XXIII, Pope, quoted, 20

K

Kingwood College (Texas), 108–11

Kirkwood Community College (Iowa), 148–50

L

laboratory, mobile, 123

laboratory exercises, 104, 146; and classroom instruction, 85; for genetic fingerprinting, 94–100; and Human Genome Project, 88–90; for mobile laboratory, 123; in molecular genetics, 91–93. *See also* classroom instruction

laboratory techniques, 110

Last Harvest (Raeburn), 60

law: and disclosure of genetic information, 11–17; and health insurance, 66; and Human Genome Project, 46–47. *See also* court decisions; legal issues

Lawrence Berkeley National Laboratory, 114–15

learning community, 142–46, 148–50

lectures, classroom, 132–33

legal issues: of biotechnology, 145–46; of genetics revolution, 135–36

life science, 139

life span, human, 69–70

Locke, John, 35–36

M

malaria, 71

mapping, chromosome, 42, 53

marketing, of biotechnology program, 115

McClintock, Barbara, 52

McCormick, Richard A., S.J., 21

Meaney, Michael, quoted, 140

medical technology, laboratory exercises, 91–93

Mendel, Gregor, 41–42

Merton, Thomas, quoted, 20

Mesa Community College (Arizona), 137–40

Methanococcus jannaschii, sequencing of, 1–2

microbes: DNA separation, 74; sequencing of, 1–2

Microcosm (Gilder), 57

microscopy, 41–42

Middlesex Community College (Massachusetts), 103–6

Midwest National Archives (Chicago), 85–86

Misericordia House (Chicago), 86

modifications, genetic, in agriculture, 58–59

Moore, John, 9–10

Morgan, Thomas H., 51–52

Morris, Desmond, quoted, 33

Mount Sinai Hospital (Chicago), Reproductive Physiology Lab, 86

mutations, 43, 55. *See also* genetic diseases

N

National Center for Human Genome Research, 46

National Human Genome Research Institute, 1

National Institutes of Health, 41

National Science Foundation, 114, 139; Advanced Technology Education grants, 103–4; Collaborative Excellence in Teacher Preparation grants, 30

National Skill Standards for the Bioscience Industry, 113–14

nature-nurture controversy, 139

needs-based approach to disclosure of genetic information, 13–14

networking, 114–15

Nietzsche, Friedrich, and idea of “superman,” 35

NIH-DOE-ELSI Working Group, 135

Northern California Center for Applied Biological Technologies, 115

nurses, role of, 72

nursing, 69–72

O

Online Mendelian Inheritance in Man database, 55

organisms, genetically modified. *See* genetically modified organisms (GMOs)

organisms, model, 46

outreach, public, 122–24

P

pain relief, 71

Panikkar, Raimon, *Dwelling Place for Wisdom*, 22

partnerships, education-industry, 112–21

patents, on genetic materials, 9–10

pedigree, 79–81; construction of, 85–86

pedigree problems, classroom use of, 31–32

peroxidase, purification of, 88–89

pharmacogenetics, 71

phenylketonuria, 52, 70–71

philosophical issues, of Human Genome Project, 130, 132

plasmids, 54

Plato, *Republic*, 35

policy issues: of applied genetics, 144; of Human Genome Project, 130–31, 136

polymerase chain reaction (PCR) analysis, 95–96

portfolios, student, 106, 119–20

President’s Commission for the Study in Ethical Problems in Medicine, 15

privacy, 46, 66. *See also* disclosure of genetic information; ethical issues

privatization. *See* bioindustry

professional development, 114

proteins: isolation and analysis of, 123; as macromolecules, 92; synthesis of, 44

psychologists, and Human Genome Project, 131–32

public awareness of biotechnology, 52

public opinion, role of, 28

Q

questionnaires, use in classroom, 132

R

Raeburn, Paul, *Last Harvest*, 60

recombinant DNA technology, 75–76

recruitment, 118

religion, and science, 18–22

Republic (Plato), 35

research, applied vs. basic, 131

resources: for building genetics program, 50; for interdisciplinary biotechnology program, 106–7; for job literacy, 111; for mobile biotechnology laboratory, 124–25; for multidisciplinary program, 133, 141, 150–51; for multimedia teaching, 82–84; for study of ethical issues, 17, 22; for study of gene therapy, 81; for study of genetic engineering, 63–64; for study of genetics concepts, 56; for study of genetics revolution, 47, 86–87; for study of Human Genome Project, 67, 133. *See also* laboratory exercises

restriction fragment length polymorphism (RFLP) analysis, 95–96

retroviruses, 52

Richland College (Texas), Science Multimedia Laboratory, 82–84

rights-based approach to disclosure of genetic information, 13

risk, potential, of transgenic crops, 59–60

RNA (ribonucleic acid), 43–44, 73–74

Road Ahead (Gates), 21–22

role playing, in classroom instruction, 66

S

San Diego City College, 117–21

Sandoz, 9

scenarios: “crime,” 97–100; “duty to disclose,” 16

scheduling, 149; of human genetics course, 68

science, and religion, 18–22

Science and Religion (Haught), 20

Scientist, 67

Seattle Central Community College, 94–100

Secretary’s Commission on Achieving Necessary Skills, 114

segregation, genetic law of, 42

self-awareness, human, 34

sickle-cell anemia, 79–81. *See also* genetic diseases

simulation, classroom use of, 138–39

Skagi Valley College (Washington), 142–46

skills, job literacy, 109–11, 113–14, 119–20

Skill Standards for the Bioscience Industry, 119

Slavery and Freedom (Berdyayev), 18

social issues: of biotechnology, 145–46; dramatization of, 23–25;
of genetics revolution, 18–29; historical, 33–37; of Human
Genome Project, 46–47, 130–31

social sciences, and genetics course, 137–40

sociology, 142–46

software, educational, 82–84, 138–39

statistical analysis, 99–100

Stratagene Cloning, Inc., 117

Strauss, Leo, quoted, 37

students, community college, 57–58; assessment of, 119–20;
and course evaluations, 120; engagement in learning, 138–39;
and multidisciplinary approach, 129–30; and multimedia
approach, 84; nonscience, 134–36, 148–50; success stories,
115

“superman,” Nietzschean, 35

T

teachers, high school, 122–24; collaboration in biotechnology
program, 113

teaching. *See* classroom instruction

technology, classroom, 83

technology transfer, 46

telomeres, 53

theater, role of, 23–25

theme courses, 148–49

theology, and genetics revolution, 18–22

Tolins, Jonathan, *Twilight of the Gods*, 23–25

Topoisomerases, 52

transcription, DNA, 44, 73

translation, RNA, 44, 73–74

transplants, tissue and organ, 13

transposons, 52

Twilight of the Gods (Tolins), 23–25

U

universities, and biotechnology research, 7–8

University of Chicago, 86

University of Iowa, 150

University of Wisconsin, Waukesha, 129–33

U.S. Department of Energy, 41, 115

U.S. Office of Technology Assessment, 41

Utopian Motherhood (Francouer), 20–21

V

variable number of tandem repeats (VNTRs), 95–96

videotapes: Nova series, 86–87; *Secret of Life* series (Suzuki),
66–67

viral recombination, 60

visual prospecting, 54

Von Tschermak, Erich, 42

W

Watson, James, 42, 52, 73, 132

Wertz, Dorothy, 13–16, 132

Wiener, Norbert, quoted, 7

William Paterson College (New Jersey), 122–24

Wilson, E. O., quoted, 34

workshops: biotechnology, 122–24; summer, 115

World Wide Web, 67

This monograph comprises 30 papers based on award-winning concepts presented at the groundbreaking conference *The Genetics Revolution: A Catalyst for Education and Public Policy*, held at North Lake College in Dallas in March 1996. The conference examined the latest research in genetics and related issues from the perspective of the community college. Participants had the opportunity to learn from national experts in the fields of human genetics, public policy, ethics, and industrial applications.

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