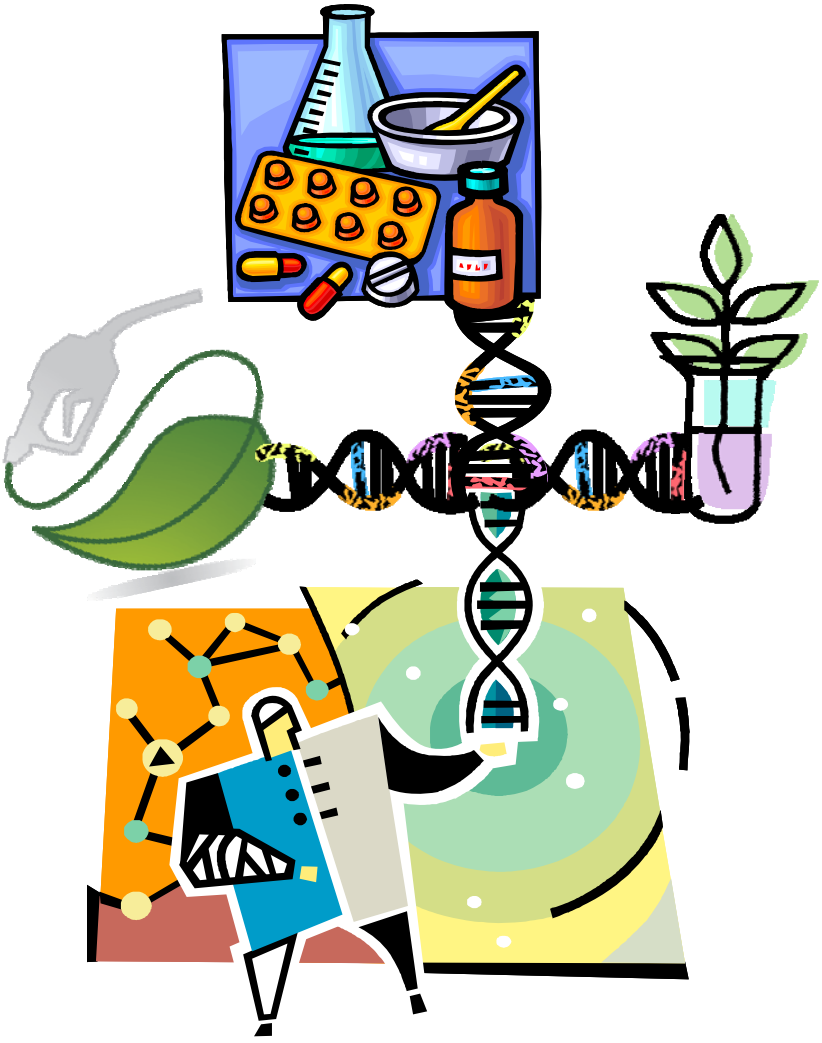
Introduction to Biotechnology:

A Georgia Teachers Resource Manual



Bioscience Curriculum for CTAE and Science Credit

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What is Biotechnology?

Welcome to the stimulating and quickly evolving field of Biotechnology! This manual is intended to assist you in teaching the biotechnology standards recently drafted and adopted by the Georgia Department of Education for the Introduction to Biotechnology course. This manual is intended to serve two purposes: 1) to connect the Georgia DOE standards with the content covered in a high school level Biotechnology textbook and 2) to help teachers become familiar with instructional strategies and lessons in order to deliver the course content. Biotechnology is a unique and rewarding opportunity for both the students and the teachers that "transforms" scientific knowledge into practice.

Recommended Text: Biotechnology: Science for the New Millennium by Ellyn Daugherty available from EMC-Paradigm Publishing
Curriculum Materials Available: http://www.emcp.com/product_catalog/index.php?GroupID=170/

- Text and Encore Multimedia CD, Experiencing Biotechnology, offering
    - Flash animations of key biotechnology concepts
    - Videos demonstrating lab procedures using the scientific method
    - Quizzes in two modes: practice and scores-reported
    - Full glossary with pronunciations
- Lab Manual with activities and experiments for every chapter
- Text/Encore CD and Lab Manual Package
- Lab Notebook
- Text/Encore CD, Lab Manual, and Lab Notebook Package
- Instructor's Guide (printed) and CD-ROM Package
    - Includes model answers, evaluation guides, teaching hints, course planning tools, PowerPoint presentations
- Test Generator and Item Bank
    - Create your own tests or use predefined, ready-to-activate tests
    - Use any combination of hundreds of multiple-choice, true/false, matching, and short-answer items
    - Deliver tests on print, LAN, or WAN platforms
    - Create a Web site for your class to manage their testing
- Course Planner: Comprehensive Lesson Plans
    - Guidelines for structuring an introductory biotechnology course
    - Pedagogical resources needed to teach a successful course
    - A complete lesson plan for every section of every chapter in the textbook and lab manual
    - Lesson plan models presented in case you want to design your own lesson structure
- Internet Resource Center:
    - Student resources include self-quizzes with reportable results for teachers, study aids, Web links, PowerPoint presentations

    - Instructor resources include syllabus suggestions, tests and assessments, answer keys, PowerPoint presentations, course objectives, and Web links
- Class Connections (WebCT and Blackboard)
    - Includes course syllabi, assignments, quizzes, tests, Web links, and projects

WHAT IS BIOTECHNOLOGY?

Biotechnology is the use or manipulation of an organism or the components of an organism. By this definition, the origins of biotechnology date back to when people first began to domesticate animals and cultivate food crops. While those early applications are certainly still employed today, modern biotechnology is primarily associated with molecular biology, cloning, and genetic engineering. Within the last 50 years, the biological sciences were revolutionized by several key discoveries that enabled the rapid evolution of the biosciences. These discoveries enabled scientists to isolate and manipulate genes, which has facilitated the growth of the biotechnology industry.

INTRODUCTION TO BIOTECHNOLOGY COURSE

This course introduces students to the fundamental scientific principals of biotechnology, bioethics, the variety of careers in biosciences, as well as the commercial and regulatory characteristics of the biosciences. The Introduction to Biotechnology course emphasizes how key concepts from biology, chemistry, and physics apply to modern applications within the biological sciences. The knowledge and skills gained in this course provide students with a broad understanding of biotechnology and the impact it makes on society. As students work to master the content, they mirror what scientists and technicians are doing in scientific laboratories. A significant part of the course involves actual and simulated research being done in actual laboratories world-wide, which gives students the unique opportunity to carry out the world changing experiments about which they are learning. To accomplish this goal, the course is especially laboratory intensive, and students spend 50-75% of class time carrying out actual experiments. This focus on working knowledge allows students to learn and practice the skills that they would actually use in the field of biotechnology and build up the practical skill set of each student. Ultimately, the content and skills covered offers all students the opportunity to acquire basic competencies required for an entry-level position in any biotechnology company. The target audience includes all students interested in attending any college or technical schools by providing foundational concepts and established laboratory procedures in a broad spectrum of disciplines such as biology, chemistry, biochemistry, molecular biology, microbiology, genetics, and immunology.

Workers in biotechnology create, design, develop, and evaluate systems and products such as artificial organs, artificial limbs, medication information systems, medical equipment and instrumentation. Tasks associated with careers in biotechnology include researching new materials for biomedical equipment, evaluating the safety of such equipment, utilizing computer simulation of the body's organs and systems, designing and developing new procedures and equipment for detecting disease, and advising hospitals and other medical facilities on the use of new and existing medical equipment. Major employers include research and development companies, medicine manufacturers, medical equipment and supply manufacturers, and private hospitals.

BIOTECHNOLOOGY INDUSTRY FACTS

- The biotechnology industry emerged in the 1970s, based largely on a new recombinant DNA technology.
- Biotechnology has created more than 200 new therapies and vaccines, including products to treat cancer, diabetes, HIV/ AIDS and autoimmune disorders.
- There are hundreds of biotech drug products and vaccines currently in clinical trials targeting more than 200 diseases, including various cancers, Alzheimer's disease, heart disease, diabetes, multiple sclerosis, AIDS and arthritis.
- Biotechnology is responsible for hundreds of medical diagnostic tests that keep the blood supply safe from HIV and detect other conditions early enough to be successfully treated. Home pregnancy tests are also biotechnology diagnostic products.
- Agricultural biotechnology benefits farmers, consumers and the environment—by increasing yields and farm income, decreasing pesticide applications and improving soil and water quality, and providing healthful foods for consumers.
- Environmental biotech products make it possible to clean up hazardous waste more efficiently by harnessing pollution eating microbes.
- Industrial biotech applications have led to cleaner processes that produce less waste and use less energy and water.
- DNA fingerprinting, a biotech process, has dramatically improved criminal investigation and forensic medicine. It has also led to significant advances in anthropology and wildlife management.
- The biotech industry is regulated by the U.S. Food and Drug Administration (FDA), the Environmental Protection Agency (EPA) and the Department of Agriculture (USDA).
- In 1982, recombinant human insulin became the first biotech therapy to earn FDA approval. The product was developed by Genentech and Eli Lilly and Co.

From *The Guide to Biotechnology* by the Biotechnology Industry Organization (BIO)
Editors Roxanna Guilford-Blake & Debbie Strickland www.bio.org

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Introduction to Biotechnology: Georgia Standards

Course Title: Introduction to Biotechnology

Course Description: Introduction to Biotechnology integrates the fundamental concepts of life and physical sciences together with the basic laboratory skills necessary in the biological sciences. This course may serve as either the second course in the Biotechnology Research and Development pathway or as an independent science elective. Introduction to Biotechnology introduces students to the fundamentals of biotechnology, current trends and careers in biotechnology, and the business, regulatory, and ethical aspects of biotechnology. The knowledge and skills gained in this course will provide students with a broad understanding of biotechnology and its impact on society.

Introduction to Biotechnology is intended to meet the needs of a diverse body of learners. The target audience includes all students who choose postsecondary education, providing them with foundational concepts and established laboratory protocols in a broad spectrum of disciplines such as biology, chemistry, biochemistry, biotechnology, microbiology, molecular and cell biology, genetics, and immunology. In addition, the course has the potential to foster scientific literacy and improve student success on the Georgia High School Graduation Test and to provide entry into the biotechnology career field.

Co-Requisite – Content
HS-IBT-1. Students will demonstrate understanding of required safety practices and procedures in the classroom and laboratory environment.

a. Define health and safety regulations, including Occupational Safety and Health Administration (OSHA), Environmental Protection Agency (EPA), and Right to Know and demonstrate procedures for documenting and reporting hazards and compliance e.g., CFR1910.1450.
b. Demonstrate health and safety practices, including use of Material Safety Data Sheets (MSDS), appropriate personal protective equipment (PPE) for the situation, emergency equipment, storage of chemicals, reagents and compounds, and maintenance of equipment.
c. Demonstrate disaster preparedness procedures for each emergency situation –fire prevention and the emergency evacuation plan, inclement weather, school and workplace violence, bomb threat, and biotechnology related emergencies.
d. Demonstrate knowledge of standard precautions including proper storage, handling and disposal of biohazards materials.
e. Demonstrate the ability to follow Standard Operating Procedures (SOP).

Academic Standards:
HS-IBT-2. Students will understand the basis for biotechnology products and how such products affect the quality of life.

a. Describe the major scientific discoveries that lead to development of recombinant DNA technology, including those in the fields of biology, chemistry, genetics, and microbiology, and explain how these advances in DNA technology are used today
b. Identify past and current discoveries and developments in fields such as, agriculture, diagnostics, medical devices, pharmaceuticals, and research and development.
c. Justify the steps in production and delivery of a product made using recombinant DNA technology.
d. Discuss the implications of the genomics and proteomics on biotechnology and current healthcare.

HS-IBT-3. Students will analyze careers in research and development, human health and diagnostics, biomanufacturing, environmental applications, and agriculture that utilize biotechnology.

a. Describe the educational requirements and responsibilities for various positions within the biotechnology industry.
b. Compare and contrast careers within academic, government, and private sectors.
c. Develop a portfolio documenting education, experiences, and acquired skills for a specific careers.
d. Demonstrate understanding of the career development planning process and the process of life-long learning.
e. Describe the role of Student Organizations (e.g., HOSA, FBLA, Key Club, and BETA) and their importance in leadership development.
f. Demonstrate an understanding of the nature of employer-employee relationships.

HS-IBT-4. Students will demonstrate how concepts of physical science connect to biochemical applications and techniques.

a. Calculate and prepare buffers, stock solutions, and reagents.
b. Analyze and apply the concepts of homeostasis and molar relationships to biochemical reactions.
c. Draw conclusions regarding protein function and structure as it relates to the pH of a solution.
d. Analyze enzyme activity using assays for reactants and products.
e. Utilize electrophoresis, chromatography, microscopy and spectrophotometry to identify, separate and to draw conclusions about biological molecules.
f. Use antibody specificity for antigens to test for the presence of protein (e.g., ELISA, Western Blot, antibody staining).

HS-IBT-5. Students will compare and contrast common organisms used in biotechnology and relate the manipulation of living organisms to product and procedure development.

a. Distinguish between prokaryotic cells, eukaryotic cells, and non-living entities such as viruses.
b. Describe the characteristics and life cycles of model organisms used in biotechnology, including bacteria (e.g., E. coli), fungi (e.g., yeasts and Aspergillus), and animals (e.g., C. elegans, fruit flies, and rodents).

c. Monitor how environmental factors affect the growth of cells and model organisms in the laboratory.
d. Apply the basic concepts of cell growth to manipulate cultures under aseptic conditions in the laboratory.
e. Perform transformations, including competency, selection, antibiotic resistance, and analysis of transformation efficiency.

HS-IBT-6. Students will demonstrate how manipulation of nucleic acids through genetic engineering (recombinant DNA and RNA technologies) alters the function of proteins and subsequent cellular processes.

a. Describe the function of DNA, RNA, and protein in living cells and the Central Dogma.
b. Demonstrate how the structure of DNA influences its function, analysis, and manipulation.
    - Isolate genomic and recombinant DNA from cells and solutions and analyze its purity and concentration.
    - Explain and demonstrate the principles involved in DNA analysis via agarose gel electrophoresis.
    - Describe previous and current DNA sequencing technologies.
c. Explain the role of enzymes (e.g., restriction enzymes, DNA polymerases, and nucleases) in the production and manipulation of DNA molecules.
d. Determine and analyze the effect of qualitative and quantitative changes of specific proteins on cell function.

HS-IBT-7. Students will analyze economic, social, ethical, and legal issues related to the use of biotechnology.

a. Differentiate between moral, ethical, and legal biotechnology issues.
b. Research ethical issues presented by evolving science, including genetically modified foods, cloning, bioterrorism, gene therapy, and stem cells.
c. Compare and contrast attitudes about the use of biotechnology regionally, nationally, and internationally.
d. Evaluate the regulatory policies impacting biotechnology research - e.g., use of animals in research and applications of recombinant DNA.

Co-Requisite – Characteristics of Science
Habits of Mind

SCSh1. Students will evaluate the importance of curiosity, honesty, openness, and skepticism in science.

a. Exhibit the above traits in their own scientific activities.
b. Recognize that different explanations often can be given for the same evidence.
c. Explain that further understanding of scientific problems relies on the design and execution of new experiments which may reinforce or weaken opposing explanations.

SCSh2. Students will use standard safety practices for all classroom laboratory and field investigations.

a. Follow correct procedures for use of scientific apparatus.
b. Demonstrate appropriate technique in all laboratory situations.
c. Follow correct protocol for identifying and reporting safety problems and violations.

SCSh3. Students will identify and investigate problems scientifically.

a. Suggest reasonable hypotheses for identified problems.
b. Develop procedures for solving scientific problems.
c. Collect, organize and record appropriate data.
d. Graphically compare and analyze data points and/or summary statistics.
e. Develop reasonable conclusions based on data collected.
f. Evaluate whether conclusions are reasonable by reviewing the process and checking against other available information.

SCSh4. Students use tools and instruments for observing, measuring, and manipulating scientific equipment and materials.

a. Develop and use systematic procedures for recording and organizing information.
b. Use technology to produce tables and graphs.
c. Use technology to develop, test, and revise experimental or mathematical models.

CSh5. Students will demonstrate the computation and estimation skills necessary for analyzing data and developing reasonable scientific explanations.

a. Trace the source on any large disparity between estimated and calculated answers to problems.
b. Consider possible effects of measurement errors on calculations.
c. Recognize the relationship between accuracy and precision.
d. Express appropriate numbers of significant figures for calculated data, using scientific notation where appropriate.
e. Solve scientific problems by substituting quantitative values, using dimensional analysis and/or simple algebraic formulas as appropriate.

SCSh6. Students will communicate scientific investigations and information clearly.

a. Write clear, coherent laboratory reports related to scientific investigations.
b. Write clear, coherent accounts of current scientific issues, including possible alternative interpretations of the data.
c. Use data as evidence to support scientific arguments and claims in written or oral presentations.
d. Participate in group discussions of scientific investigation and current scientific issues.

The Nature of Science

SCSh7. Students analyze how scientific knowledge is developed.
Students recognize that:

a. The universe is a vast single system in which the basic principles are the same everywhere.
b. Universal principles are discovered through observation and experimental verification.
c. From time to time, major shifts occur in the scientific view of how the world works. More often, however, the changes that take place in the body of scientific knowledge are small modifications of prior knowledge. Major shifts in scientific views typically occur after the observation of a new phenomenon or an insightful interpretation of existing data by an individual or research group.
d. Hypotheses often cause scientists to develop new experiments that produce additional data.
e. Testing, revising, and occasionally rejecting new and old theories never ends.

SCSh8. Students will understand important features of the process of scientific inquiry. Students will apply the following to inquiry learning practices:

a. Scientific investigators control the conditions of their experiments in order to produce valuable data.
b. Scientific researchers are expected to critically assess the quality of data including possible sources of bias in their investigations' hypotheses, observations, data analyses, and interpretations.
c. Scientists use practices such as peer review and publication to reinforce the integrity of scientific activity and reporting.
d. The merit of a new theory is judged by how well scientific data are explained by the new theory.
e. The ultimate goal of science is to develop an understanding of the natural universe which is free of biases.
f. Science disciplines and traditions differ from one another in what is studied, techniques used, and outcomes sought.

Reading Standard Comment

After the elementary years, students are seriously engaged in reading for learning. This process sweeps across all disciplinary domains, extending even to the area of personal learning. Students encounter a variety of informational as well as fictional texts, and they experience text in all genres and modes of discourse. In the study of various disciplines of learning (language arts, mathematics, science, social studies), students must learn through reading the communities of discourse of each of those disciplines. Each subject has its own specific vocabulary, and for students to excel in all subjects, they must learn the specific vocabulary of those subject areas in context.

Beginning with the middle grades years, students begin to self-select reading materials based on personal interests established through classroom learning. Students become curious about science, mathematics, history, and literature as they form contexts for those subjects related to their personal and classroom experiences. As students explore academic areas through reading, they develop favorite subjects and become confident in their verbal discourse about those subjects.

Reading across curriculum content develops both academic and personal interests in students. As students read, they develop both content and contextual vocabulary. They also build good habits for reading, researching, and learning. The Reading Across the Curriculum standard focuses on the academic and personal skills students acquire as they read in all areas of learning.

SCSh9. Students will enhance reading in all curriculum areas by:

a. Reading in all curriculum areas
- Read a minimum of 25 grade-level appropriate books per year from a variety of subject disciplines and participate in discussions related to curricular learning in all areas.
- Read both informational and fictional texts in a variety of genres and modes of discourse.
- Read technical texts related to various subject areas.

b. Discussing books
- Discuss messages and themes from books in all subject areas.
- Respond to a variety of texts in multiple modes of discourse.
- Relate messages and themes from one subject area to messages and themes in another area.
- Evaluate the merit of texts in every subject discipline.
- Examine author's purpose in writing.
- Recognize the features of disciplinary texts.

c. Building vocabulary knowledge
- Demonstrate an understanding of contextual vocabulary in various subjects.
- Use content vocabulary in writing and speaking.
- Explore understanding of new words found in subject area texts.

d. Establishing context
- Explore life experiences related to subject area content.
- Discuss in both writing and speaking how certain words are subject area related.
- Determine strategies for finding content and contextual meaning for unknown words.

CTAE Foundation Skills

The Foundation Skills for Career, Technical and Agricultural Education (CTAE) are critical competencies that students pursuing any career pathway should exhibit to be successful. As core standards for all career pathways in all program concentrations, these skills link career, technical and agricultural education to the state's academic performance standards.

The CTAE Foundation Skills are aligned to the foundation of the U. S. Department of Education's 16 Career Clusters. Endorsed by the National Career Technical Education Foundation (NCTEF) and the National Association of State Directors of Career Technical Education Consortium (NASDCTEc), the foundation skills were developed from an analysis of all pathways in the sixteen occupational areas. These standards were identified and validated by a national advisory group of employers, secondary and postsecondary educators, labor associations, and other stakeholders. The Knowledge and Skills provide learners a broad foundation for managing lifelong learning and career transitions in a rapidly changing economy.

CTAE-FS-1 Technical Skills: Learners achieve technical content skills necessary to pursue the full range of careers for all pathways in the program concentration.

CTAE-FS-2 Academic Foundations: Learners achieve state academic standards at or above grade level.

CTAE-FS-3 Communications: Learners use various communication skills in expressing and interpreting information.

CTAE-FS-4 Problem Solving and Critical Thinking: Learners define and solve problems, and use problem-solving and improvement methods and tools.

CTAE-FS-5 Information Technology Applications: Learners use multiple information technology devices to access, organize, process, transmit, and communicate information.

CTAE-FS-6 Systems: Learners understand a variety of organizational structures and functions.

CTAE-FS-7 Safety, Health and Environment: Learners employ safety, health and environmental management systems in corporations and comprehend their importance to organizational performance and regulatory compliance.

CTAE-FS-8 Leadership and Teamwork: Learners apply leadership and teamwork skills in collaborating with others to accomplish organizational goals and objectives.

CTAE-FS-9 Ethics and Legal Responsibilities: Learners commit to work ethics, behavior, and legal responsibilities in the workplace.

CTAE-FS-10 Career Development: Learners plan and manage academic-career plans and employment relations.

CTAE-FS-11 Entrepreneurship: Learners demonstrate understanding of concepts, processes, and behaviors associated with successful entrepreneurial performance

3
Building a Biotechnology Program

A. Assessing your needs

Introduction to Biotechnology is a unique course consisting of both the traditional Science instructional elements combined with established Career, Technical, and Agriculture Education (CTAE) standards. The result is a course that is ideal for meeting the needs of a diverse body of learners while cultivating 21st century workplace skills. The nature of the curriculum and standards places a priority on the application of content knowledge and laboratory skills. The ideal Biotechnology student, like the ideal employee, possesses a willingness to learn, a good work ethic, and works well with others. Since Biotechnology covers so many areas of science, most students find a specific area that peaks their interest and passion, which may very well lead to a future career.

As you consider developing a Biotechnology course in your school, you will need to carefully consider your school's unique needs. For example, are you a CTAE program looking to add the Biotechnology Pathway, or are you a traditional high school looking to add science courses to help your students meet the fourth year science requirement? While the content covered in these two situations would be exactly the same, the course delivery and recruitment may look quite different. The former will place this course as a crucial part in the CTAE Biotechnology Pathway that prepares students for an advanced Biotechnology course and possible internships, yet the latter option will be filling a specific need as a stand alone course. These situations present different challenges with regards to student recruitment, funding, and overall purpose.

The following two charts are intended to help weigh the needs and considerations with the support available in your area. Use the questions included to help guide you through the process of developing a Biotechnology program and communicating with your leadership and community partners. It is best to address the Needs and Considerations before thinking about the support. If your school has specific needs that the Biotechnology curriculum addresses, the support will most likely be available via your community or district.

After you are able to discuss the "Needs" and "Support" issues with your leadership, you will have great perspective on the Biotechnology environment in your area. Given the rapid growth of the Biotechnology industry over the last 20 years and the strong presence of bioscience companies in Georgia, almost any school is a fertile field for a Biotechnology course. As you weigh the matters and particular issues identified, the two most important pieces of a vibrant Biotechnology program will be described in the following sections.

NEEDS & CONSIDERATIONS

Student	School District	Community
Will this be a part of a CTAE Program?	What are the goals of this course/ program?	How many Biotech firms are located in your area?
Is this course intended specifically to fulfill the 4th Science requirement?	What curriculum materials will be used to support instruction?	Are there local postsecondary Biotech programs in the area?
What are the postsecondary destinations of your students?	What is the annual budget available for Biotechnology?	What support is available from community partners?
What are the students' career and job aspirations?	How will Biotech help our students on the Georgia High School Graduation Exam?	What are the needs of the biotech employers in your area?
What was the student's favorite science class?	What is the target student population?	
Who will be teaching the course?	Who will facilitate the community and district collaborations?	
	What are the initial expenses?	

SUPPORT:

Financial	Administrative	Community
How much do you have to spend on books and curriculum resources (lab manuals)?	Are there reasonable and clear expectations for the Biotechnology course?	What workplace experiences are available?
How much money do you have for durable equipment?	What are the Staff Development and Training opportunities available?	What opportunities for fieldtrips are available?
What is your yearly budget for consumable supplies?	Will there be a designated lab classroom?	Are there willing guest speakers in your area?
Do you have any money for field trips?	What will the class size be in your Biotechnology class considering students will be doing labs 50-75% of the time?	Would Biotech organizations be willing to provide input into lessons?
What will be your primary sources of funding?	What counseling and administrative support will be available for student recruitment?	What grant opportunities exist to support a Biotechnology program?

B. Recruiting support & students

Many students and adults lack an appreciation for biotechnology and many of terms associated with biotechnology are misunderstood, which presents a unique challenge when trying to recruit students or nonscientific community support. If you ask a group of high school students what biotechnology is, you will get a variety of answers ranging from a fairly accurate definition to ideas of "playing god" and human cloning. Therefore, as you recruit students and support you will need to be prepared to accurately describe a diverse and evolving field. You will also need to help students make connections with aspects of biotechnology that they are familiar with. Genetically modified foods, forensic science applications (any of the modern crime dramas on TV), medical advances and therapies, insulin, selective breeding, dairy products like cheese and yogurt, and antibiotics are among the diverse applications of biotechnology in our lives. Using these connections to everyday aspects of our lives helps students better understand biotechnology and creates interest in the course.

Depending on your schools unique "Needs," you will want to take one of several approaches to student recruitment. Recruiting students could be broadly focused on students in prerequisite courses which feed students into a Biotechnology course. This allows the recruitment to be catered specifically to students at specific levels i.e., honors vs. regular level students. A simple brochure in combination with a brief presentation in front of prospective students seems to work well. Alternatively, students could be identified based upon their prior success in previous courses, such as Biology, or predicted success on the High School Graduation Exam and encouraged by faculty members to register for Biotechnology to increase their likelihood for success during their 11th and 12th grade years. Since the Biotechnology course covers some of the physical science and a great deal of biology on the Georgia High School Graduation Test, it may significantly improve student performance on that critical assessment. It is expected that this course will increase student engagement and educational experience due to the practical nature of biotechnology and the focus on skill development.

C. "Know-how" is secondary to "Can-do"

Most of the discussion prior to this point was focused on the resources required to establish a Biotechnology course. Yet, the most critical component of a successful Biotechnology Program at the high school level has not been addressed. Who will teach Biotechnology at your school? As is the case in any successful classroom, the most important ingredient in a successful laboratory learning environment is the Biotechnology teacher. The Biotechnology teacher does not need to have a PhD in Molecular Biology or 10 years of experience in the Bioscience industry. It is truly a "no previous experience required" position because the most important features of a Biotechnology teacher are a willingness to learn and enthusiasm. There are numerous opportunities for professional development and training offered throughout the state during both the summer and the school year. Additionally, the teacher will be able to learn many of the techniques and skills alongside their students, and it sold be noted that the students truly enjoy learning alongside the teacher. Therefore, it is not necessary for the teacher to have experience with all of the techniques, merely a desire and willingness to learn alongside the students.

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Materials and Supplies

One of the more unique aspects of this course of study is that students are learning both the applications and how to use modern scientific laboratory equipment. Therefore, an integral component of any Biotechnology course is the technology required to provide an authentic learning experience. Like any technology course, the equipment cost and requirements are a fundamental consideration, but the benefits to the students are significant. Schools with AP Biology courses will already have some of these essential components, and while they will be used more extensively in the Biotechnology class, it is certainly possible to share them between the courses. The equipment and supplies listed below are based upon the labs from the Biotechnology Lab Manual by Ellyn Daugherty, which align with the GPS for Introduction to Biotechnology.

The equipment is sorted based upon the supplier whose product provides the best quality for the cost. The total estimated equipment cost is around $30,000 per school, but that can be reduced to under $20,000 based upon crucial considerations and possible alternatives. Two items combine to account for almost $10,000, a UV spectrophotometer, and autoclave. Yet, lower cost options are available for both, but it is only recommended in the case of the autoclave (Sargent Welch has a Portable Electric Sterilizer, WLS58617-A for around $715.09). The UV spectrophotometer is necessary to measure nucleic acid concentrations and purity, and without this tool, students cannot use a spectrophotometer to measure DNA quantity and purity (HS-IBT-6b), which means that this standard would have to be accomplished by another means, such as gel electrophoresis and that is more difficult and less accurate and not a current standard laboratory procedure. In addition, a few other specific items are highlighted that might be eliminated without dramatically diminishing the instructional quality.

Biotechnology Equipment List

Equipment	Catalog #	Amt	Cost	Total	Notes
Company BioRad					
Mini-Sub Cell GT 7x7	166-4270EDU	8	$179.00	$1,432.00	
Power-Pac Basic	166-5050EDU	2	$325.00	$650.00	
Mini-Trans Blot protein	170-3930EDU	4	$298.00	$1,192.00	optional
Micropipette 2-20	166-0506EDU	8	$159.00	$1,272.00	
Micropipette 20-200	166-0507EDU	8	$159.00	$1,272.00	
Micropipette 100-1000	166-0508EDU	8	$159.00	$1,272.00	Possible to reduce to 4 as an extreme cost savings measure.
Micro centrifuge	166-0603EDU	2	$260.00	$520.00	
Incubation Oven	166-0501EDU	2	$295.00	$590.00	
Water Bath	166-0504EDU	1	$505.00	$505.00	
Transilluminator	**170-7950EDU**	**1**	**$428.00**	**$428.00**	**optional**
Rocking Platform	**166-0709EDU**	**1**	**$575.00**	**$575.00**	**optional**
Pipet Tips 0.5-10 TBR 14	223-9354EDU	1	$36.00	$36.00	

Pipet Tips TBR 35	223-9347EDU	1	$36.00	$36.00	
Pipet Tips TBR 40	223-9350EDU	1	$39.00	$39.00	
Protein Tips	223-9917EDU	1	$43.00	$43.00	
Xculda Tips (PCR)	211-2001EDU	1	$98.00	$98.00	
1.5 ml tubes	223-9480EDU	2	$19.00	$38.00	
PCR Tubes	223-9473EDU	1	$25.00	$25.00	
Disposable Cuvettes	223-9950EDU	5	$10.00	$50.00	
Disposable Cuvettes	223-9955EDU	5	$10.00	$50.00	
Long wave UV Lamps	166-0500EDU	4	$35.00	$140.00	
Company Fisher					
Autoclave	S63100	1	$7,112.00	$7,112.00	Optional, a sterilizer cost about $800 or a microwave can be used to sterilize most solutions.
pH Meter	S66888	2	$192.00	$384.00	
Balance	S67064	2	$307.00	$614.00	
Hot Plate/Stirrer	14-259-230	2	$385.00	$770.00	
Stirplate	11-510-53	4	$159.00	$636.00	
Erlenmeyer Flask 125ml	07-250-089	1	$37.67	$37.67	12 pk
Erlenmeyer Flask 250ml	07-250-090	1	$38.99	$38.99	12 pk
Erlenmeyer Flask 500ml	07-250-091	2	$24.56	$49.12	6 pk
Erlenmeyer Flask 1L	07-250-092	2	$39.93	$79.86	6 pk
Bottles Graduated autoclavable 500ml	03-405-33	1	$53.00	$53.00	12 pk
Bottles Graduated autoclavable 1L	03-405-34	2	$31.00	$62.00	6 pk
Stir Bars A	14-512-149	12	$5.94	$71.28	
Stir Bars B	14-512-148	12	$5.15	$61.80	
PCR Racks	05-541-55	2	$56.28	$112.56	10 pk
Parafilm	13-374-10	1	$26.40	$26.40	
4 way racks	03-448-17	3	$34.86	$104.58	5 pk
Graduated cylinder 100 ml	08-572D	12	$181.43	$2,177.16	
Graduated cylinder 500 ml	08-572F	8	$212.95	$1,703.60	
50 ml Centrifuge Tubes	05-539-7	1	$209.31	$209.31	cs
15 ml Centrifuge Tubes	05-538-53F	1	$173.92	$173.92	cs
Supplier: Sargent-Welch					
Inoculating Loop With Nickel-Chromium Wire & Aluminum Handle	WLS62730-10	8	$4.05	$32.40	
Pipet Pump Blue, for 1-2 mL pipets	WLB53502-222	8	$21.25	$170.00	
Pipet Pump Green, for 5-10 mL pipets	WLB53502-233	8	$23.25	$186.00	
Edvocycler (25 well Thermal cycler)	WLS541	1	$1,895.00	$1,895.00	Can be shared between schools
Genway UV/Vis Spectrophotometer **If eliminated, another spec must be available for the GPS requirements.**	WLB1763-22	1	$3,909.75	$3,909.75	UV spec is a necessary optional item. The last optional item to eliminate.
1.7 mL Reaction Tube Rack, five assorted colors, 5/PK	WLB10011-272	4	$45.00	$180.00	

Floating rack (1.7 mL tubes), 4/PK	WLS31170-A	2	$27.00	$54.00	
Hot Hand, Hand Protector	WLS1774-22	5	$18.75	$93.75	
Grand Total				**$31,261.15**	
Grand Total of Essential Equipment				**$18,844.40**	

Biotechnology Supply List

This list represents the essential chemicals and supplies for the suggested labs to accomplish delivery of drafted Georgia Performance Standards for Introduction to Biotechnology. Please carefully exam these labs and your current resources before ordering! Please see the following website www.sargentwelch.com/biotech for complete materials lists for Biotechnology.

Sargent-Welch Item Description	Catalog No.	Qty	Unit Price	Total Price	Lab #	NOTES
95% Ethanol, 4L, 2/CS	WLC95064-07	1	$85.00	$85.00		
Agarose, 100 g	WLBIC800668	1	$132.09	$132.09		
alpha-Amylase, from B. subtilis, 100 g	WLC94446-02	1	$20.00	$20.00		
Ampicillin, 25 g	WLBEM-2200	1	$156.60	$156.60		store @ 4°C
Aspergillus sp, plate culture	WLBVW85V8100	1	$10.25	$10.25		living
BamH I enzyme, 2500 U, with 10X reaction buffer	WLBPAR6021	1	$44.29	$44.29		store @ -20°C
Bradford Reagent, AMRESCO	WLB100514-184	1	$105.99	$105.99		store @ 4°C
BSA Bovine Serum Albumin, 100 g	WLBEM-2930	1	$176.00	$176.00		store @ 4°C
Calcium Nitrate, 4-Hydrate, 500 g	WLC98025-06	1	$13.14	$13.14		
Cellulase, 25 g	WLC94484-02	1	$29.51	$29.51		
Cellulose,100 g	WLC94485-04	1	$15.75	$15.75		
Cheesecloth, 3 ft X 15 ft	WLS19795	1	$5.75	$5.75		
Chymosin, Recombinant Rennin, 100mL	WLB1030	1	$19.25	$19.25		
COOMASSIE* Brilliant Blue R-250	WLBEM-3340	1	$75.00	$75.00		
Crystal Violet Staining Solution, 2% (Methanol), 100 mL, Flammable	WLC95055-04	1	$5.71	$5.71		
Cupric Sulfate 5-Hydrate, 500 g, Reagent Fine Crystals	WLC94767-06	1	$21.00	$21.00		
Deoxyribonucleic Acid, Salmon Testes, 1.0 g	WLB1626	1	$112.50	$112.50		store @ 4°C
Dialysis Tubing, 1" width, 100 ft/PK	WLS25275-AF	1	$48.90	$48.90		
Disposable Tissues/Wipes	WLS19813-A	10	$2.90	$29.00		
DNA Marker 100 bp ladder (DNA Sizing Standards), 250 µL	WLBPAG2101	1	$105.75	$105.75		store @ -20°C
DNA Polymerase (buffer	PAM3001	1	$28.00	$28.00		store

included)						@ -20°C
EcoRI enzyme, 5000 U	WLBPAR6011	1	$31.89	$31.89		store @ -20°C
EDTA, Disodium salt, 100 g	WLC94538-04	1	$18.40	$18.40		
Electrophoresis Buffer Concentrate, 40X TAE	WLBPAV4281	1	$74.59	$74.59		
Ethidium Bromide, 10 mL	WLBIB40075	1	$35.99	$35.99		
Fructose, 500 g	WLC94512-06	1	$21.10	$21.10		
Galactose, 100 g	WLC94505-04	1	$48.00	$48.00		
Gel Loading Dye 10X, 20 ml	101319-854	1	$29.97	$29.97		
Gelatin, 500 g	WLC94551-06	1	$21.00	$21.00		
Glucose (Dextrose), 500 g, anhydrous	WLB90000-908	1	$31.50	$31.50		
Glucose test strips, 50/PK	WLC4862Y	1	$17.95	$17.95		
Grams Iodine, Biological Stain (Aqueous) (1.85% Iodine/3.05%Iodide), 1L	WLC94144-07	1	$20.57	$20.57		
HinD III enzyme, 5000 U	WLBPAR6041	1	$27.09	$27.09		store @ -20°C
Hydrochloric Acid Solution, 6N, 1L	WLC97040-07	1	$12.55	$12.55		
Kinetin, 99% 1G	WLBAAA13720-03	1	$25.29	$25.29		
Lactose, 500 g	WLC94588-06	1	$18.14	$18.14		
Lambda, cut w/HinDIII, 1X100 µg, 0.5 µg/µL	WLBPAZG1711	1	$60.09	$60.09		Store @ -20°C
Lambda, uncut, 5X200 µg	WLBPAZD1501	1	$75.09	$75.09		
Lysol® Disinfectant, conc. 1 gallon	WLB14227-215	1	$58.00	$58.00		
Lysozyme, 5 g	WLBEM-5950	1	$97.25	$97.25		
Maltose, 500 g	WLC94602-06	1	$19.30	$19.30		
Methylene Blue Stain, 1%, 100 mL	WLC94619-04	1	$5.30	$5.30		
Parafilm®, 125 ft, 4"	WLS65710-A	1	$19.65	$19.65		
Pasteur Pipet Bulb, 72/CS	82024-554	1	$62.80	$62.80		
Pasteur Pipets, 9", 250/PK	WLS69647-H	1	$14.20	$14.20		
Pectinase, 25 g	WLBTCP0026-25G	1	$41.79	$41.79		
Petri Dishes, 100 X 15 mm, sterile, 20/PK	WLS26028	10	$6.95	$69.50		
Petri Dishes, 60 X 15 mm, sterile, 20/PK	WLS26028-60	10	$9.70	$97.00		
Petroleum Ether, 1L	WLC95112-07	1	$49.00	$49.00		
Pipets, 10 mL, multi-pack, 500/CS	WLB53283-722	2	$180.00	$360.00		
Pipets, 5 mL, multi-pack, 500/CS	WLB53283-720	2	$164.00	$328.00		
Pipets, Transfer, 3 mL, Graduated 0.25 mL, 500/PK	WLS69684-40B	1	$25.70	$25.70		

Plant Tissue Culture Agar, 8g	WLB602891	1	$11.85	$11.85		
Potassium Acetate, Crystals, 500 g	WLC94204-06	1	$21.83	$21.83		
Protease, Pronase, 50 units	WLB80601-406	1	$114.59	$114.59		
Protein Molecular Weight Markers, Prestained	WLB172-84	1	$52.00	$52.00		store @ -20°C
Rennin, Bovine, 25 g	WLC94666-02	1	$28.60	$28.60		store @ 4°C
RNase, 10 mg/mL solution, 1 mL	WLB80509-764	1	$64.89	$64.89		store @ -20°C
Sodium Carbonate, anhydrous, 500 g	WLC94291-06	1	$6.20	$6.20		
Sodium Dodecyl Sulfate (SDS), 100 g	WLC94320-04	1	$11.98	$11.98		
Sodium Monophosphate, Dibasic, Anhydrous	WLC94330-06	1	$18.00	$18.00		
Sodium Phosphate, Monobasic, Monohydrate NaH2PO4 X H20, 500 g	WLBEM-8290	1	$71.25	$71.25		
Syringe Filter, 25 mm, Cellulose, Luer-lock, 0.2 µm, 50/PK	WLB22002-110	1	$99.95	$99.95		
Syringe, Plastic, 10 mL, 100/PK	WLBBD309604	1	$17.25	$17.25		
Test Tube, VWR, 25 X 200 cm, 48/PK	WLS1737-08	1	$66.25	$66.25		
TRIS	WLBIB70142	1	$57.29	$57.29		
TRIS-HCl	WLBIC816124	1	$84.29	$84.29		
TRITON X-100 10%, 100 mL	WLBVW8609-0	1	$18.50	$18.50		
Wizard Genomic DNA Purification Kit	WLB82017-730	1	$145.00	$145.00		
Yeast, 100g	WLC94734-04	1	$12.30	$12.30		
TOTAL Consumables Cost (without any discount)				**$3,958.20**		

Other common laboratory materials include:

- Calculators
- Pens, permanent ink markers, black
- Waxed paper, 1 box
- Collander, 1 ea
- Cheesecloth, 1 pkg
- Cups, styrofoam
- Rubber mallet (for crushing ice) 1 ea
- Alcohol (1 Liter, packed in absorbent material) 1 bottle
- Sodium chloride
- Soap, Liquid Detergent 1 bottle
- Phenol red
- Water, sterile
- Aluminum foil 1 roll
- Tape (extra), labeling several
- Thermometers, 2 ea
- Toothpicks,
- Baggies, Ziploc, small 2 boxes
- Baggies, Ziploc, large 1 box
- Gloves (Small) 2 boxes
- Gloves (Medium) 2 boxes
- Gloves (Large) 2 boxes
- Goggles, 1 pair/ per student 4 pr
- Spatulas 4 ea
- Refrigerator & freezer
- Food coloring 1 box

5

The Biotechnology Classroom

A. Classroom Set-up

Practically almost any classroom can be converted into a Biotech teaching lab, but there are certain essential features that the room must possess. The primary room considerations are adequate areas for safe, appropriate instruction and the necessary storage space. The ideal classroom will have a traditional instructional area with desks and whiteboard and a separate laboratory area with adequate work space for all students. These unique areas allow students to complete paper work in desks and lab work at their designated lab station, which allows students to work safely and comfortably and the teacher to manage the students efficiently. However, not all schools have such an ideal environment available, and this should not be an obstacle to offering the Biotechnology course. The essential biotech classroom components are already available at most schools and will only require minor modification to set up a successful teaching environment for Biotechnology.

The minimal requirements for a safe and functional learning environment are straightforward. There needs to be an adequate amount of tabletop/ countertop space. A minimum of three linear feet of countertop/ tabletop edge space per student is optimal. The work surfaces must be resin tops where fire and caustic chemicals are used, and the resin top work surfaces are recommended on all work areas. One wall needs water, gas line jets, and sinks (1 sink per 10 students). The lab also needs to have appropriate storage for all equipment and supplies, including glassware, incubators, consumable materials, chemicals, balances, etc. This might consist of built-in cabinets or portable storage units. Due to the temperature sensitive nature of many of the reagents, the lab will require 1-2 larger refrigerators and freezers or several smaller refrigerators with -20°C freezers.

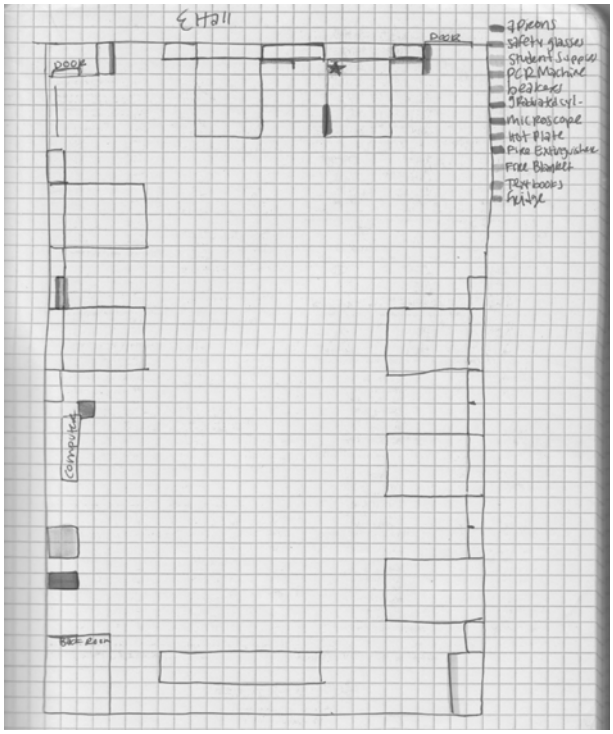


Figure 5.1 Sample drawing of lab environment made by a student with the location of Safety Materials indicated.

An important part of working in any laboratory is the proper and consistent use of instruments and equipment. When setting up the working areas in the lab, it is best if there can be dedicated, permanent work areas for instruments and equipment used in such regular activities as weighing out chemicals, running gels, incubators and water baths. While difficult if the room is used for multiple different courses, this set-up allows students to work independently, minimizes teacher preparation, and allows students to work without having to ask the instructor for materials and supplies. The dedicated space is both familiar and makes all the resources more readily available. Whether you can dedicate space in such a manner or not, it is advised to have students explore the laboratory early in the semester and have them document the location of all key safety and experimental resources by making a detailed drawing of the lab (see example on the right). This familiarizes the students with the working environment and

empowers them to take ownership of the classroom experience. This drawing can be added to as the course progresses to demonstrate the location of almost all lab resources.

B. Lab Safety

There are appropriate methods and precautions that must be taken in any biological laboratory. This includes procedures for safe handling and storage of hazardous chemicals and biological materials. All laboratory workers, including students, are expected to learn, understand and comply with all environmental, health and safety procedures and agree to follow the local science safety policy. Each worker should know the location and proper use of each of the following: gloves, goggles, safety shower, eyewash station, biohazard container, broken glass disposal box, fire extinguisher, first aid kit, and hazardous material spill cleanup kit. Students need to understand the importance of safe and appropriate behavior and consequences need to be clearly communicated and applied when students violate lab rules.

Below is an example of general laboratory safety rules used in an actual Biotechnology classroom. Both students and parents must sign a laboratory contract that states they understand and agree to the following safety rules.

General laboratory safety rules

1. Never eat or drink in the lab. No gum chewing. Do not bring food or drinks into the lab.
2. Wear UV-rated safety glasses or goggles at all times while working in the lab.
3. Know the location and appropriate use of safety equipment.
4. Dispose of all materials and chemicals correctly.
5. Be aware of potential hazards. Read all labels and directions before using chemicals or equipment.
6. Label all solutions and chemicals clearly.
7. You must wear a lab coat or apron for protection as necessary.
8. Avoid wearing contact lenses in the laboratory. Chemical vapors can permeate lenses or become trapped behind them, potentially damaging your lenses or eyes.
9. Remove your gloves and wash your hands immediately after handling chemicals or fluids. While wearing gloves, do not touch door handles, water taps, computers, telephones or other objects that may be touched by people not wearing gloves.
10. Keep book bags and other personal items off the tables and floor during lab. You can store your personal items on empty chairs so that they are out of the way.
11. Do not wear loose or flowing clothing or dangling jewelry in the laboratory. Pin up long hair or confine it under a hat.
12. Do not wear sandals or open-toed shoes. Flat-heeled, full-coverage shoes of leather or other impermeable material are best.
13. Report spills and broken glass immediately to your instructor, and always dispose of broken glass in its designated container. Do not place non-glass items in these containers.
14. Clean up your work stations, wipe your lab bench and wash your hands before leaving the lab room.

C. Classroom Management

The Biotechnology classroom is similar to many laboratory science and technology-based classrooms, yet it is different from many traditional classrooms. The presence of an extensive amount of advanced laboratory equipment and inexperienced students requires clear, consistent expectations and classroom procedures. Spending a few days to weeks focused on communicating the standard classroom procedures and expectations will help students to learn conduct themselves in an appropriate, professional manner. In addition, many teachers of Biotechnology refer to their students as employees, which may help students understand the unique nature of the class. To help with developing the workplace-like philosophy, the following strategies are recommended for establishing a professional biotech environment. Those are an employee contract/syllabus (Page 23) and stock ticker (Page 24).

Employee Contract/Syllabus

BROOKWOOD BIOENGINEERING **Fall 2009 Employee Contract & Syllabus**

Instructor/Supervisor: Dr. Jonathon Wetherington Lab/Office: E-14
E-mail: jonathan_wetherington@gwinnett.k12.ga.us Main office: (770) 972-7642
Office Hours: Tues, Thurs, & Fri 2:15-3:15 in E-14

"Employee Contract"

Congratulations on your appointment to Brookwood Bioengineering. This course is designed to get you ready for training, positions, and careers in the bioscience industry. The goals and expectations are different than in most courses. The goals for Fall Semester are two-fold: master the content and skills expected **and** complete a Research Project.

EXPECTATIONS:

1. You are expected to be in class (at work), seated, with materials, ready to work when the bell rings.

- **Every day**, you are expected to have the following materials:
  - your legal, scientific notebook
  - a blue pen
  - a metric ruler
  - a calculator
  - a glue stick

2. You are expected to develop lab and industry skills with at least 80% competency.
3. You are expected to work in a safe and professional manner in the lab as directed by the lab instructor/supervisor.
4. You are expected to respect the rights of others to learn and work.
5. You are expected to participate in all labs and discussions, and take notes as necessary.
6. If you miss a class, it is your responsibility to make up the work/time in the required time period.

EVALUATION: Since this course is designed to prepare you for the workforce, you will be evaluated in a fashion similar to the evaluation techniques used in industry. Your evaluation (grade) and continued participation are based on the following 5 categories:

CATEGORY	EXPLANATION
Record Keeping	All data and information will be kept in a legal, scientific notebook.
Content Based Tests & Quizzes	Objective evaluation of content knowledge, through quizzes and midterm exam, and skill development through skill quizzes and lab practical exams.
In-class Participation and Homework	Self-directed labs will constitute 40-50% of class time. Students are expected to exhibit cooperative, mature, and safe behavior in the lab at all times. Any student who violates lab safety rules may be removed from the lab, may receive a zero, or may lose lab privileges for the semester. *If you miss a workday, you must make it up promptly. (See * below)*
Research Project	During Fall Semester, you are expected to design, develop, and conduct a Science Fair Experiment. Further details are available online.
Final Exam	The semester ends with a cumulative objective exam (15%) and a performance final (5%).

*Makeups are by appointment only, on Tuesdays and Thursdays, within one week of absence. Each absence affects your grade. You may "make up" up to 5 missed class hours/semester without penalty. Make up work that is not completed within the allotted time will be assigned a zero. The student is responsible for scheduling a time for make up work with the teacher.

Biotechnology students will have opportunities not available to others, including sophisticated laboratory research, guest speakers, "meaningful" readings/activities/discussions/ presentations, field trips, and workplace experiences. It requires a commitment from the students and the adults in his or her life. Because it is often hard to control the timing of experiments, occasionally students will be expected to be in the lab at unscheduled times. **I understand the commitment required for this course.**

Student's Signature _____ **E-mail _____**

Parent's Signature _____ **Phone No. /_____**

Biotech Stock Ticker

A classroom management technique that allows instructors to clearly communicate positive and corrective feedback to students is a classroom "stock ticker." Traditionally, a stock ticker is a device or display showing the current price and/or volumes of stock trades as the data becomes available. This information helps investors and executives to understand the value of specific corporations. As a corporation achieves goals and meets or exceeds expectations, the value of a corporation's stock generally increases. If the corporation and its employees do not meet expectations or behave inappropriately, the stock value usually decreases, thus, there is a constant correlation between corporate behavior and stock value.

The biotechnology classroom can be an unconventional, asynchronous learning environment with students working in cooperative groups. To provide feedback regarding their behavior and performance, the Biotech Stock Ticker was developed to allow the teacher to communicate feedback regarding performance and behavior of the student lab groups in an efficient manner. Students are told to develop a corporate name for their lab group, which will now be referred as a corporation. Corporations are typically lab groups consisting of 2-4 students working at a specific lab station. A section of the classroom whiteboard/ chalkboard is then set aside as the "Biotech Stock Ticker," and there is data table set up with columns to represent class periods and rows for lab groups on this section of the board (*Figure 5.2, right*). Each box in the table contains the corporations name, stock price, and most recent fluctuation indicated by an arrow either up or down and the value it changed by.

Lab Station	1st period	2nd period
1	Corn 23 ↓ 2	Goldfish 23 ↓ 2
2	Soybeans 31 ↑ 6	260/280 23 ↓ 2
3	DNA 31 ↑ 6	Photometer 31 ↑ 6
4	RNA 31 ↑ 6	Hazards 31 ↑ 6
5	Antisense 23 ↓ 2	Safe-T 31 ↑ 6
6	Organism 31 ↑ 6	Transformers 23 ↓ 2
7	Ethics 31 ↑ 6	Aqua 23 ↓ 2

Figure 5.2 Biotech Stock Ticker Chart.

The "corporations" stock price goes up and down based upon performance on key workplace behaviors, such as being on task, following laboratory rules and procedures, working in a cooperative, professional manner, cleaning and maintaining the lab station, finishing experiments in the time allotted, and documenting experimental progress appropriately in the lab notebooks. Based upon students' performance along these key proficiencies, the corporation's stock price goes up and down to reflect the teacher's informal evaluation of the student's performance as part of a team. These stock points can then become a resource that the teacher can use to establish a reward system, where the students can use their stock points for teacher established rewards. This system has been used to effectively change inappropriate behaviors, encourage correct work habits, and identify ineffective lab groups quantitatively.

6
Introduction to Biotechnology
Possible Pacing Guide

Topic/ Concept	Time	Biotechnology Instructional Calendar	Resources
Characteristics of Science	On-Going	**Nature of Science, Habits of the Mind, and CTAE Foundational Skills**	
Careers in Biotechnology	On-Going	**HS-IBT-3. Students will analyze careers in research and development, human health and diagnostics, biomanufacturing, environmental applications, and agriculture that utilize biotechnology.** a. Describe the educational requirements and responsibilities for various positions within the biotechnology industry. b. Compare and contrast careers within academic, government, and private sectors. c. Develop a portfolio documenting education, experiences, and acquired skills for a specific careers. d. Demonstrate understanding of the career development planning process and the process of life-long learning. e. Describe the role of Student Organizations (e.g., HOSA, FBLA, Key Club, and BETA) and their importance in leadership development. f. Demonstrate an understanding of the nature of employer-employee relationships.	
1st Semester			
Development of Biotechnology Products	Weeks 1-3	**HS-IBT-2. Students will understand the basis for biotechnology products and how such products affect the quality of life.** a. Describe the major scientific discoveries that lead to development of recombinant DNA technology, including those in the fields of biology, chemistry, genetics, and microbiology, and explain how these advances in DNA technology are used today b. Identify past and current discoveries and developments in fields such as, agriculture, diagnostics, medical devices, pharmaceuticals, and research and development. c. Justify the steps in production and delivery of a product made using recombinant DNA technology. d. Discuss the implications of the genomics and proteomics on biotechnology and current healthcare.	**Ch. 1**

Topic/ Concept	Time	Biotechnology Instructional Calendar	Resources
Bioethics	Week 4 and on-going	**HS-IBT-7. Students will analyze economic, social, ethical, and legal issues related to the use of biotechnology.** a. Differentiate between moral, ethical, and legal biotechnology issues. b. Research ethical issues presented by evolving science, including genetically modified foods, cloning, bioterrorism, gene therapy, and stem cells. c. Compare and contrast attitudes about the use of biotechnology regionally, nationally, and internationally. d. Evaluate the regulatory policies impacting biotechnology research - e.g., use of animals in research and applications of recombinant DNA.	**Ch. 1**
Laboratory Procedures & Safety	Week 5-12	**HS-IBT-1. Students will demonstrate understanding of required safety practices and procedures in the classroom and laboratory environment.** a. Define health and safety regulations, including Occupational Health and Safety Administration (OSHA), Environmental Protection Agency (EPA), and Right to Know and demonstrate procedures for documenting and reporting hazards and compliance e.g., CFR1910.1450. b. Demonstrate health and safety practices, including use of Material Safety Data Sheets (MSDS), appropriate personal protective equipment (PPE) for the situation, emergency equipment, storage of chemicals, reagents and compounds, and maintenance of equipment. c. Demonstrate disaster preparedness procedures for each emergency situation –fire prevention and the emergency evacuation plan, inclement weather, school and workplace violence, bomb threat, and biotechnology related emergencies. d. Demonstrate knowledge of standard precautions including proper storage, handling and disposal of biohazardous materials. e. Demonstrate the ability to follow Standard Operating Procedures (SOP).	**Ch 3**
Biotechniques and Applications		**HS-IBT-4. Students will demonstrate how concepts of physical science connect to biochemical applications and techniques.** a. Calculate and prepare buffers, stock solutions, and reagents. b. Analyze and apply the concepts of homeostasis and molar relationships to biochemical reactions. c. Draw conclusions regarding protein function and structure as it relates to the pH of a solution. d. Analyze enzyme activity using assays for reactants and products. e. Utilize electrophoresis, chromatography, microscopy and spectrophotometry to identify, separate and to draw conclusions about biological molecules.	

Topic/ Concept	Suggested Time	Biotechnology Instructional Calendar	Resources
Genetic Engineering	Weeks 13-18	**HS-IBT-6. Students will demonstrate how manipulation of nucleic acids through genetic engineering (recombinant DNA and RNA technologies) alters the function of proteins and subsequent cellular processes.** a. Describe the function of DNA, RNA, and protein in living cells and the Central Dogma. b. Demonstrate how the structure of DNA influences its function, analysis, and manipulation.	**Ch 2,4,5**
2nd Semester			
Genetic Engineering -- DNA Manipulation	Weeks 19-23	**HS-IBT-6. Students will demonstrate how manipulation of nucleic acids through genetic engineering (recombinant DNA and RNA technologies) alters the function of proteins and subsequent cellular processes.** c. Explain the role of enzymes (e.g., restriction enzymes, DNA polymerases, and nucleases) in the production and manipulation of DNA molecules. d. Determine and analyze the effect of qualitative and quantitative changes of specific proteins on cell function.	**Ch 2,4,5, 14**
Organisms in Biotechnology	Weeks 24-36	**HS-IBT-5. Students will compare and contrast common organisms used in biotechnology and relate the manipulation of living organisms to product and procedure development.** a. Distinguish between prokaryotic cells, eukaryotic cells, and non-living entities such as viruses. b. Describe the characteristics and life cycles of model organisms used in biotechnology, including bacteria (e.g., E. coli), fungi (e.g., yeasts and Aspergillus), and animals (e.g., C. elegans, fruit flies, and rodents). c. Monitor how environmental factors affect the growth of cells and model organisms in the laboratory. d. Apply the basic concepts of cell growth to manipulate cultures under aseptic conditions in the laboratory. e. Perform transformations, including competency, selection, antibiotic resistance, and analysis of transformation efficiency. **HS-IBT-4. Students will demonstrate how concepts of physical science connect to biochemical applications and techniques.** e. Utilize electrophoresis, chromatography, microscopy and spectrophotometry to identify, separate and to draw conclusions about biological molecules. f. Use antibody specificity for antigens to test for the presence of protein (e.g., ELISA, Western Blot, antibody staining).	**Ch 7,8,9**

7
Development of Biotechnology Products

A. GPS Standards for HS-IBT-2

B. Essential Questions and Answers

C. Essential Vocabulary

D. Textbook Correlations

E. Suggested Labs and Lessons

F. General tips and Misconceptions

A. HS-IBT-2. Students will understand the basis for biotechnology products and how such products affect the quality of life.

a. Describe the major scientific discoveries that lead to development of recombinant DNA technology, including those in the fields of biology, chemistry, genetics, and microbiology, and explain how these advances in DNA technology are used today
b. Identify past and current discoveries and developments in fields such as agriculture, diagnostics, medical devices, pharmaceuticals, and research and development.
c. Justify the steps in production and delivery of a product made using recombinant DNA technology.
d. Discuss the implications of the genomics and proteomics on biotechnology and current healthcare.

B. Essential Questions and Answers:

1. **What is Biotechnology?**

Biotechnology is the use of organisms, cells, and biological molecules to solve problems or make useful products.

2. **What are the major discoveries that led to the development of recombinant DNA technology?**

- In 1865, Gregor Mendel studies garden peas and discovers that genetic traits are passed from parents to offspring in a predictable way—the laws of heredity.
- In 1953, James Watson and Francis Crick deduced DNA's structure from experimental clues and model building.

- Discovery of enzymes that affect DNA, such as restriction enzymes, DNA polymerase, and DNA ligase.
- In 1972, Paul Berg and colleagues created the first recombinant DNA molecules, using restriction enzymes and DNA ligase.
- In 1982, the first recombinant DNA-based drug (recombinant human insulin) was being marketed and produced.
- In 1983, Kary Mullis invents the polymerase chain reaction (PCR) technique. PCR, which uses heat and enzymes to make unlimited copies of genes.

3. How is DNA technology being used in modern applications?

Today, we use recombinant DNA techniques to:

- Create new medicines and vaccines
- Increase agricultural yields
- Decrease the environmental impact and production costs of agriculture
- Improve the nutritional value of food
- Remove environmental pollutants and contaminants
- Reduce allergens in food products
- Develop biological based products
- Produce biofuels

4. Trace the steps in the production and delivery of a product made using recombinant DNA technology?

<u>Stages in Product Development</u>
Product Identification → Research & Development → Small-scale Manufacturing → Testing for Safety and Efficacy → Manufacturing → Sales and Marketing

5. What are the implications of genomics on biotechnology and current healthcare?

Genomics is the scientific study of the genome and the role genes play in determining cell structure, directing growth, and controlling biological functions. Knowing the complete or partial DNA sequences of individual genes or markers provides useful information, even if the precise details of gene function remain unknown. For example, genomics data can:

- Use genetic information to develop individual drugs and therapies (*Pharmacogenomics)*
- Understand how genetic differences affect the effectiveness of medicines
- Understanding how genes affect one another in different species
- Isolate specific recombinant molecules
- Identify infectious microbes
- Identify the genes involved in disease processes
- Improve crop yield and pest resistance

6. What are the implications of proteomics on biotechnology and current healthcare?

Genes exert their effects through proteins, so gene expression results in protein production. The collection of proteins in a cell is known as its *proteome*, and *proteomics* is the study of the structure, function, location and interaction of proteins within and between cells. The collection of proteins in an entire organism is also referred as its *proteome* (e.g., *the human proteome*). The sequence of amino acids and modification after translation affects the shape and, therefore, the function of a protein. Any changes to a protein affect a protein's form and function, which might explain how the 25,000 human genes in the genome can make the hundreds of thousands of proteins that comprise the human proteome.

Proteomics is developing tools to address the many applications of proteomics such as:

- which proteins are produced by certain cells
- determining how age, environmental conditions and disease affects the protein production
- how can biotechnology alter protein production in organisms
- discovering the functions of all proteins.
- understanding how proteins changes occur in disease development
- discerning how a protein interacts with other proteins

7. What are the significant past and current developments in the major fields of biotechnology?

Timeline (Adapted from the Guide to Biotechnology by Biotechnology Industry Organization)

8000 B.C.

- Humans domesticate crops and livestock.

4000–2000 B.C.

- Biotechnology is first used to leaven bread and ferment beer with yeast (Egypt).
- Production of cheese and fermentation of wine begin (Sumeria, China and Egypt).
- Babylonians control date palm breeding by selectively pollinating female trees with pollen from certain male trees.

500 B.C.

- The first antibiotic is put to use: moldy soybean curds used to treat boils (China).

A.D. 100

- Powdered chrysanthemums are the first insecticide (China).

1322

- An Arab chieftain first uses artificial insemination to produce superior horses.

1590–1608

- The compound microscope is invented in the Netherlands.
- English physicist Robert Hooke discovers existence of the cell.

1675

- Dutch scientist Antoine van Leeuwenhoek discovers bacteria.

1761

- German botanist Joseph Koelreuter reports successful crossbreeding of crop plants in different species.

1797

- English surgeon Edward Jenner pioneers vaccination by inoculating a child with a viral vaccine to protect him from smallpox.

1835–1855

- German scientists Mathias Schleiden and Theodor Schwann propose that all organisms are composed of cells, and German pathologist Rudolf Virchow declares, "Every cell arises from a cell."

1857

- French chemist and microbiologist Louis Pasteur proposes microbes cause fermentation.

1859

- English naturalist Charles Darwin publishes the theory of evolution by natural selection.

1865

- The science of genetics begins: Austrian monk Gregor Mendel studies garden peas and discovers that genetic traits are passed from parents to offspring in a predictable way—the laws of heredity. Mendel's discoveries were largely ignored until the early 20th century.

1900

- Fruit flies (*Drosophila melanogaster*) are used in early studies of genes. The fruit fly remains an important model organism today.
- American agronomist and inventor George Washington Carver seeks new industrial uses for agricultural feedstocks.

1914

- Bacteria are used to treat sewage for the first time in Manchester, England.

1915

- Phages, or bacterial viruses, are discovered.

1919

- The word *biotechnology* is first used in print.

1928

- Scottish scientist Alexander Fleming discovers penicillin.
- German botanist Friedrich Laibach first uses embryo rescue to obtain hybrids from wide crosses in crop plants—known today as hybridization.

1930

- U.S. Congress passes the Plant Patent Act, enabling the products of plant breeding to be patented.

1933

- Hybrid corn, developed by Henry Wallace in the 1920s, is commercialized. Growing hybrid corn eliminates the option of saving seeds. The remarkable yields outweigh the increased costs of annual seed purchases, and by 1945, hybrid corn accounts for 78 percent of U.S.-grown corn.

1942

- The electron microscope is used to identify and characterize a bacteriophage—a virus that infects bacteria.
- Penicillin is mass-produced in microbes.

1943

- German botanist Friedrich Laibach proposes *Arabidopsis thaliana* as a model organism for plant genetic research.

1944

- Canadian-born American bacteriologist Oswald Avery and colleagues discover that DNA carries genetic information.

1949

- American chemist Linus Pauling shows that sickle cell anemia is a "molecular disease" resulting from a mutation in the protein molecule hemoglobin.

1951

- Artificial insemination of livestock using frozen semen is accomplished.

1953

- The scientific journal *Nature* publishes James Watson and Francis Crick's manuscript describing the double helical structure of DNA, which marks the beginning of the modern era of genetics.

1956

- American biochemist and physician Arthur Kornberg discovers the enzyme DNA polymerase I, leading to an understanding of how DNA is replicated.

1958

- Sickle cell anemia is shown to occur due to a change of a single amino acid.
- DNA is made in a test tube for the first time.

1960

- Messenger RNA is discovered.

1961

- USDA registers the first biopesticide: *Bacillus thuringiensis*, or Bt.

1963

- New wheat varieties developed by American agricultural scientist, Norman Borlaug, increase yields by 70 percent.

1966

- The genetic code is cracked, demonstrating that a sequence of three nucleotide bases (a codon) determines each of 20 amino acids. (Two more amino acids have since been discovered.)

1970

- Norman Borlaug receives the Nobel Peace Prize.
- Scientists discover restriction enzymes that cut and splice genetic material, opening the way for gene cloning.

1971

- The first complete synthesis of a gene is completed.

1973

- American biochemists Stanley Cohen and Herbert Boyer perfect techniques to cut and paste DNA (using restriction enzymes and ligases) and reproduce the new DNA in bacteria.

1975

- The first monoclonal antibodies are produced.

1976

- Recombinant DNA pioneer Herbert Boyer co-founds Genentech, the first company based on the technology.

1977

- A human gene is expressed in bacteria for the first time.
- Procedures are developed for rapidly sequencing long sections of DNA using electrophoresis.

1980

- The U.S. Supreme Court, in the landmark case *Diamond v. Chakrabarty*, approves the principle of patenting organisms, which allows the Exxon oil company to patent an oil-eating microorganism.

1981

- Scientists at Ohio University produce the first transgenic animals by transferring genes from other animals into mice.
- A Chinese scientist becomes the first to clone a fish—a golden carp.

1982

- The first biotech drug is approved by FDA: human insulin produced in genetically modified bacteria. Genentech and Eli Lilly developed the product.

1983

- American biochemist Kary Mullis invents the polymerase chain reaction (PCR) technique. PCR, which uses heat and enzymes to make unlimited copies of genes and gene fragments, later becomes a major tool in biotech research and product development worldwide.

1984

- The DNA fingerprinting technique (using PCR) is developed.
- The entire genome of the human immunodeficiency virus (HIV) is cloned and sequenced.

1985

- Genetic fingerprinting is entered as evidence in a courtroom.
- The NIH approves guidelines for performing gene-therapy experiments in humans.

1986

- The first recombinant vaccine for humans is approved, a vaccine for hepatitis B.
- Microbes are first used to clean up an oil spill. (The first industrial biotech patent ever issued was for a microbe to clean up oil spills; see 1980.)

1990

- Chy-Max™, an artificially produced form of the chymosin enzyme for cheese-making, is introduced. It is the first product of recombinant DNA technology in the U.S. food supply.

- The Human Genome Project—an international effort to map all the genes in the human body—is launched.

1992

- American and British scientists unveil a technique for testing embryos *in vitro* for genetic abnormalities such as cystic fibrosis and hemophilia.
- The FDA declares that transgenic foods are "not inherently dangerous" and do not require special regulation.

1994

- FDA approves the first whole food produced through biotechnology: FLAVRSAVR™ tomato.
- The first breast-cancer gene is discovered.
- Pulmozyme® (dornase alfa), a recombinant version of human DNase, is approved. The drug breaks down protein accumulation in the lungs of cystic fibrosis patients.

1997

- Dolly the sheep is unveiled in Scotland as the first animal cloned from an adult cell.
- Biotech crops are grown commercially on nearly 5 million acres worldwide. The crops are grown in Argentina, Australia, Canada, China, Mexico and the United States.

1998

- Human embryonic stem cell lines are established.
- The first complete animal genome, for the *C. elegans* roundworm, is sequenced.
- An early rough draft of the human genome map is produced, showing the locations of thousands of genes.

2000

- A rough draft of the human genome sequence is announced.
- The first complete map of a plant genome is developed: *Arabidopsis thaliana*.

2002

- A draft sequence of the rice genome is completed, marking the first genome sequence of a major food crop.
- The draft version of the complete map of the human genome is published.

2004

- GloFish®, the first biotech pet, hits the North American market.
- The laboratory-rat genome is sequenced.
- Researchers complete the sequence of the chimpanzee—humanity's closest primate relative.

2005

- Researchers at the University of Georgia successfully produce a cow cloned from the cells of a carcass.
- Scientists at Harvard University report success in converting skin cells into embryonic stem cells through fusion with existing embryonic stem cells.
- On May 7, the one billionth acre of biotech seed is planted.

2007

- Taiwanese researchers develop a biotech eucalyptus tree that ingests up to three times more carbon dioxide than conventional varieties. The biotech eucalyptus also produces less lignin and more cellulose.
- U.S. researchers announce the production of biotech cattle that cannot develop prion proteins. Prions have been implicated in the degenerative neurological disease bovine spongiform encephalopathy. (Mad Cow Disease)

2008

- The draft corn genome sequence is completed. It is only the third plant genome to be completed, after *Arabidopsis* and rice.

C. Essential Vocabulary

The following terms are essential vocabulary for mastery of the related standard.

- Antibiotics
- Antibiotic resistance
- Biochemistry
- Biotechnology
- chromosomes
- Clinical trials
- Cloning
- DNA fingerprinting
- DNA ligase
- DNA polymerase
- Food & Drug Administration (FDA)
- Gel electrophoresis
- Gene
- Gene therapy
- Genetically modified organisms (GMOs)
- Genetics
- Genomics
- Human Genome Project
- Mass production
- Molecular biology
- Pharmaceutical
- Plasmid
- Polymerase chain reaction (PCR)
- Proteomics
- Recombinant DNA
- Research & Development (R&D)
- Restriction Enzyme
- James Watson
- Francis Crick
- Rosalind Franklin

D. Textbook Correlations for *Biotechnology: Science for the New Millennium*

Chapter 1 What is Biotechnology?

Chapter 8 Modeling the Production of a Biotechnology Product

E. Suggested Labs and Lessons

1. Biotechnology: Science for the New Millennium textbook

Activity 14.4: The Evolution of the Science and Industry of Biotechnology (pages 393-396)

2. Biotechnology Laboratory Manual

Lab 1c Cheese Production: The Evolution of Cheese Making Technology

This activity is a great introductory activity to introduce students to a traditional biotech product and process that has evolved with the science. It also is a good lab experience to introduce lab safety, appropriate behavior, and the scientific method.

3. Websites:

The textbook author (Ellyn Daugherty) has several good activities on her website, which are excellent homework or classroom activities. They can found at the following website: www.bioteched.com.

Here are two that are particularly good:

- What is Biotech? Activity
  http://www.bioteched.com/coolthings/newactivities/Ch1_WhatIsBiotechActiv.pdf
- **Getting to know your textbook**
  http://www.bioteched.com/coolthings/newactivities/Ch1_GettingToKnowYourText.pdf

F. General Tips and Misconceptions

Many teachers of Biotechnology begin with this material, since it lays the foundation for future lessons and teaching. Basic questions, such as what is biotechnology and what discoveries laid the groundwork for current discoveries and research, provide students with the proper perspective on the content to be addressed. A great introductory activity to be used during the first week is to ask students or teams of students to define biotechnology and award a prize to students that can best define all fields of biotechnology. This allows students to express their prior knowledge and helps teachers build upon whatever foundational knowledge the students have.

Many students have several misconceptions regarding biotechnology. Primarily, many students are confused about what biotechnology is. Many students do not think of it only in the modern, laboratory sense. Explaining the history and critical discoveries provide students with a new appreciation for an industry that is involved in so many of their lives. In addition, students tend to only think of biotechnology with regards to human applications, like cloning and gene therapy. Most have not considered the applications of biotechnology in the agricultural, industrial, or environmental applications. Understanding these misconceptions allow teachers to start students down the path with a renewed perspective regarding biotechnology and a fresh appreciation of the technology that affects our lives everyday, which increases understanding and appreciation.

8
Careers in Biotechnology

A. GPS Standards for HS-IBT-3

B. Essential Questions and Answers

C. Essential Vocabulary

D. Textbook Correlations

E. Suggested Labs and Lessons

F. General tips and Misconceptions

A. HS-IBT-3. Students will analyze careers in research and development, human health and diagnostics, biomanufacturing, environmental applications, and agriculture that utilize biotechnology.

a. Describe the educational requirements and responsibilities for various positions within the biotechnology industry.
b. Compare and contrast careers within academic, government, and private sectors.
c. Develop a portfolio documenting education, experiences, and acquired skills for a specific careers.
d. Demonstrate understanding of the career development planning process and the process of life-long learning.
e. Describe the role of Student Organizations (e.g., HOSA, FBLA, Key Club, and BETA) and their importance in leadership development.
f. Demonstrate an understanding of the nature of employer-employee relationships.

B. Essential Questions and Answers:

1. **What are the major categories of employment positions within the biotechnology industry?**

Science Positions: Scientist, Research Associate, Biotechnician, and Lab Assistant
Nonscientific Positions: Almost any no science position can be found within biotech companies in the fields of information systems, marketing and sales, human resources, regulatory affairs, administrative, legal, clerical, and most fields of engineering

2. **What are the educational requirements for the primary positions within the biotechnology industry?**

See the Table after Question 3.

3. **What skills would be necessary for the various positions?**

Categories	**Educational requirements**	**Skills and Responsibilities**	**Salary**
Scientists	Doctorate	Manages a research team or group. Develops new procedures and projects while managing and reviewing the work of others.	$65,000-$175,000
Research Associate	Bachelor's Degree -- Masters Degree	Similar responsibilities to a Biotechnician. Also develops and runs new experiments as directed. May manage a small team of technicians.	$31,000-$80,000
Biotechnician	Associates Degree	Perform basic lab activities and more advanced procedures. May develop new assays or modify existing SOPs. May perform basic quality control assurance procedures.	$27,000-$40,000
Lab Assistant	High School Diploma + experience	Perform basic lab activities such as solution and media preparation, cell culture, basic assay applications, and lab maintenance.	$15,000-$25,000

4. **How can student organizations help prepare students leadership skills and growth?**

Student organizations help students understand the power of their voice and the strength of a group with common interests and goals. Student organizations foster leadership skills through service opportunities and responding to the needs of the local school community. As students mature in organizations, they recognize their leadership skills and are given leadership development opportunities through local activities and regional conventions.

5. How are careers in the academic, government, and private sectors similar?

Most careers in the field of biotechnology have a few basic similarities regardless of the sector. Most of the positions, especially the science positions, are going to be the same in all three sectors. A career in any of the three sectors is going to require a basic understanding of the science, an appreciation for bioethics, and a willingness to learn. The science and the use of ethics are universal to all areas of science, especially biotechnology. Particularly at the technician level, there will be very few, if any, differences across all three sectors. The primary goal on the lab technician would be to complete desired assays and experiments. Additionally, the field and professional growth is expected, so almost all employees will want to add to their skills and abilities to create to opportunities for themselves. Lastly, each of these sectors, despite their vast differences, is similar in that they all affect each other directly and indirectly via regulations, discoveries, and collaborations.

6. How are careers in the academic, government, and private sectors different?

The primary differences in careers between the three sectors are going to be related to the specific purposes of each sector, which influences the functions of each employee. Since positions within the government sector are primarily concerned with the protect and service of the citizens and the environment, careers in this sector tend to focus more on the critique and evaluation of research and the management of regional or national resources. Thus, the careers here tend to focus on testing or reviewing the research of others. The academic sector traditionally is focused on exploring unknown aspects of a field regardless of the profitability. The focus is more directed towards knowledge acquisition by the students and academic community. The two goals of academic science are to train students and scientists and to contribute via journal publication to the academic community and obtain grant funding to be able to continue to publish. The environment fosters creativity and all workers are given more freedoms for discovery in this sector. The private sector exists to generate a profit and is not controlled by the government, and careers in this field can be the most rewarding financially. Additionally, the responsibilities of individuals in the private sector are focused on serving the company instead of the people or a field of knowledge.

C. Essential Vocabulary

The following terms are essential vocabulary for mastery of the related standard.

- Academic sector
- Associates degree
- Bachelors degree
- Biomanufacturing
- Biotechnician
- Diagnostics
- Forensic Scientist
- Government
- Journal
- Lab assistant
- PhD
- Private Sector
- Professional behavior
- Quality control
- Regulatory affairs
- Research Associate
- Research and Development
- Scientist
- Technician

D. Textbook Correlations for *Biotechnology: Science for the New Millennium*

Chapter 1 What is Biotechnology?
1.5 Who does Biotechnology? Careers in the Biotechnology Industry 26

- "Biotech Career" sidebar at the beginning of every Chapter.

E. Suggested Labs and Lessons

1. Biotechnology: Science for the New Millennium textbook

Biotech Online: Finding Hot Jobs Page 26

2. Biotechnology Laboratory Manual

There are no career lessons or activities in the Laboratory Manual that accompanies the textbook.

3. Other:

There are numerous websites with content directed towards educating students about the careers and opportunities in biotechnology. The biotechnology Institute has a website with a section on career spotlights (http://www.biotechinstitute.org/careers/index.html). A simple activity could read the careers highlighted, and students could answer questions regarding specific scientists or create their own "newspaper" article or want ad highlighting the career or qualifications of one of these individuals.

F. General Tips and Misconceptions

Many students have not thought seriously about the careers or potential careers in biotechnology, and while there are certainly many options in the scientific and nonscientific fields of biotechnology, many students are not comfortable with considering a career in that industry. Whether the possibilities are too novel or abstract nature of many careers makes it too difficult for students to truly appreciate the options that are available to them is hard to say. Regardless the reason, students struggle with the abstract concept of career, so it is important to provide opportunities to students that remove the abstract nature of various careers. Guest speakers and fieldtrips allow students to interact with professionals and better relate with the person in a given career. Additionally, explicit teaching and discussion of career fields, in science and in non-science positions, helps students understand the nature of the various careers. Once students can better relate and have more familiarity with the associated careers, their appreciation and comprehension of the various skills and positions improves dramatically.

9
Bioethics and Biotechnology

A. GPS Standards for HS-IBT-7

B. Essential Questions and Answers

C. Essential Vocabulary

D. Textbook Correlations

E. Suggested Labs and Lessons

F. General tips and Misconceptions

A. HS-IBT-7. Students will analyze economic, social, ethical, and legal issues related to the use of biotechnology.

a. Differentiate between moral, ethical, and legal biotechnology issues.
b. Research ethical issues presented by evolving science, including genetically modified foods, cloning, bioterrorism, gene therapy, and stem cells.
c. Compare and contrast attitudes about the use of biotechnology regionally, nationally, and internationally.
d. Evaluate the regulatory policies impacting biotechnology research - e.g., use of animals in research and applications of recombinant DNA.

B. Essential Questions and Answers:

1. What are the differences between morals and ethics?

Morals are an individuals justifiable decisions regarding whether specific actions are right or wrong, but ethics is the study or activity of deciding what a person should do based upon rationale that supports the decision. The most significant difference is that morals effect ethical decisions and behavior because ethics are the application of moral decisions through action and behavior.

2. What is bioethics?

Bioethics is a subfield that explores ethical questions related to the life sciences. Bioethics helps people make decisions about how to the appropriate applications of biotechnology and biological science.

3. What are the characteristics of an ethical question in biotechnology?

Bioethical questions usually occur when organisms may be harmed or adversely affected. Ethical questions are different from legal questions and from questions of personal preference, since the effects of the decision have to be fully considered including the legal and personal impacts. Therefore, a bioethical question is characterized by its concern for living things and their applications, but it is justifications are not limited by only legality or personal preference.

C. Essential Vocabulary

The following terms are essential vocabulary for mastery of the related standard.

- Animal testing
- Bias
- Bioethics
- Bioterrorism
- Considerations
- Cloning
- Ethics
- FDA
- Gene therapy
- Genetically Modified Organisms
- Genetic Testing/Screening
- Morals
- Policy
- Regulatory Affairs
- Recombinant DNA
- Stem cells
- Steroids
- Vaccines

D. Textbook Correlations for *Biotechnology: Science for the New Millennium*
Chapter 1
1.6 Biotechnology with a Conscience – Bioethics 27-35

Throughout the textbook, there are numerous opportunities to discuss bioethics as students progress through the curriculum. Below is a list of these topics:

Topic	Page(s)
• **Alien DNA in my Food?**	**323**
• **Animal use**	**34-35**
• **Designer babies**	**366**
• **DNA Fingerprinting**	**396**
• **Genetic disorders and pregnancy**	**264-265**
• **Hippocratic Oath**	**205**
• **Limited medications**	**186-187**
• **Monarch butterflies**	**297**
• **Moral standards**	**27-28**
• **NSF Funding Committee**	**238-239**
• **Patent ownership for human genes**	**159**
• **Promise of gene therapy**	**128**
• **Scientific dishonesty**	**96-97**
• **Stem cells**	**65**

E. Suggested Labs and Lessons

1. **Biotechnology: Science for the New Millennium** textbook

   The textbook features several resources that are excellent tools for bringing up ethical considerations and displaying the variety of opinions in your classes. These materials could be used in a variety of ways. For example, the students could complete the textbook activities as a Bell-ringer activity or a homework assignment; students could then share their answers and most importantly their reasoning behind their decision. Some of these activities are in the Instructor Resource Center, and either the publisher or author can be contacted to acquire a login and pass code. The textbook resources can be found at: http://www.bioteched.com/coolthings.htm and http://www.emcp.com/college_resource_centers/index.php?GroupID=7376.

2. **Biotechnology Laboratory Manual**
   There are no ethics lessons or activities in the Laboratory Manual that accompanies the textbook. However, there are some questions pertaining to ethics associated with some of the labs.

3. Other Resources for Teaching Bioethics

Exploring Bioethics

This 6 module supplement was developed by the NIH Department of Bioethics and the Education Development Center to provide instructional materials on ethics to high school teachers and is an excellent supplemental resource for this standard. The supplement contains helpful points and lesson plans to guide teachers in teaching Bioethics. The materials can be presented as single instructional unit or blended into the instructional calendar. The materials and modules capture and engage students into interesting and relevant issues. The supplement is available online at: http://science.education.nih.gov/supplements/nih9/bioethics/default.htm .

This material provides excellent content and support materials to help teachers approach this difficult topic in their classrooms. Each module takes at least 3 days to go through, so it provides almost 4 weeks of lessons and content on Bioethics.

Other Bioethics Online Resources

- Kennedy Institute of Ethics High School Bioethics Curriculum Project, Georgetown University. http://highschoolbioethics.georgetown.edu/

- High School Bioethics Project, Center for Bioethics, University of Pennsylvania at http://www.highschoolbioethics.org/

- Kennedy Institute of Ethics—Library and Information Services, Georgetown University. National Reference Center for Bioethics Literature. http://bioethics.georgetown.edu/nrc/ (Includes free database resources, reference help, and "QuickBibs" -- http://bioethics.georgetown.edu/nrc/quickbibsbio.htm .)

F. General Tips and Misconceptions

People, especially students, often have a particularly hard time discerning ethical questions from questions of other types but it is crucial to understand the differences when considering ethical matters. Ethical considerations are different from legal and personal considerations. While ethical decisions should take the relevant laws into consideration, something can be illegal and ethical or unethical and legal. Frequently, the law sets an acceptable standard, but ethical standards focus on ideals, not minimally acceptable behavior. Despite the fact that ethics and the law are related to and impact each other, they are indeed separate.

Helping students to understand the differences between issues of either a legal, personal, or ethical nature will be crucial to have students understand how to address ethical issues. As it relates to bioethics, the key defining feature of ethics is whether a person or thing will be harmed or unfairly treated. This key characteristic helps students to determine if something is a bioethical matter. If there is a potential for harm, it is a bioethical question. The evaluation of ethical questions of this kind is easiest if one follows a linear process and explains their justification clearly. The justification is often more important than the ethical decision that it supports. During discussions and assignments, it is important to explain to students the importance of well evaluated and thought out decisions. This helps students to move past simple personal preference and into ethical considerations.

10
Laboratory Procedures and Safety

A. GPS Standards for HS-IBT-1

B. Essential Questions and Answers

C. Essential Vocabulary

D. Textbook Correlations

E. Suggested Labs and Lessons

F. General tips and Misconceptions

A. HS-IBT-1: Students will demonstrate understanding of required safety practices and procedures in the classroom and laboratory environment.

a. Define health and safety regulations, including Occupational Health and Safety Administration (OSHA), Environmental Protection Agency (EPA), and Right to Know and demonstrate procedures for documenting and reporting hazards and compliance e.g., CFR1910.1450.

b. Demonstrate health and safety practices, including use of Material Safety Data Sheets (MSDS), appropriate personal protective equipment (PPE) for the situation, emergency equipment, storage of chemicals, reagents and compounds, and maintenance of equipment.

c. Demonstrate disaster preparedness procedures for each emergency situation –fire prevention and the emergency evacuation plan, inclement weather, school and workplace violence, bomb threat, and biotechnology related emergencies.

d. Demonstrate knowledge of standard precautions including proper storage, handling and disposal of biohazards materials.

e. Demonstrate the ability to follow Standard Operating Procedures (SOP).

B. Essential Questions and Answers:

1. **What are the general health and safety regulations every laboratory worker should be aware of?**

Biotechnology laboratories are equipped with supplies and equipment that may pose a hazard if used carelessly or incorrectly. Unfortunately, there is no single simple formula for working safely in the laboratory because each lab presents its own unique challenges. The regulations that all laboratory worker should be aware of are OHSA regulation

CFR1910.1450, the **National Fire Protection Association Ratings for chemicals, and local facility regulations.**

NFPA Ratings (National Fire Protection Association)
Another quick assessment of a chemical's health hazards that is usually available on its container is a rating by the National Fire Protection Association (NFPA). A color-coded diamond shape lists numbers rating a hazard as:

Blue for health hazard	**Red for flammability**	**Yellow for reactivity**
0 – normal material	0 – will not burn	0 – stable
1 – slightly hazardous	1 – flash point > 200° F	1 – unstable if heated
2 – hazardous	2 – flash point > 100° F	2 – violent chemical change
3 – extreme danger	3 – flash point < 100° F	3 – shock and heat may detonate
4 – deadly	4 – flash point < 73° F	4 – may detonate

The uncolored station of the NFPA diamond is for specific hazards:

- **OX** – oxidizer compound
- **ACID** – acidic compound
- **ALK** – basic compound
- **CORR** – corrosive compound
- ~~**W**~~ – use NO WATER

2. **What are the responsibilities of the Occupational Health and Safety Administration (OSHA) as related to the bioscience laboratory?**

Congress created the Occupational Safety and Health Administration (OSHA) to ensure safe and healthful working conditions for employees by setting and enforcing standards and by providing training, outreach, education and assistance. According to CPR1910.1450, OHSA sets for the regulations for all those engaged in the laboratory use of hazardous chemicals.

3. **What processes or materials are regulated by the Environmental Protection Agency (EPA)?**

The mission of the EPA is to "protect human health and to safeguard the natural environment -- air, water and land -- upon which life depends" (www.epa.gov/aboutepa/index.html). Therefore, the EPA regulates the disposal of potential hazardous materials and the use of biotechnology products in the environment.

4. **What is the proper way to store and handle chemicals and hazardous materials in the laboratory environment?**

Chemicals should be labeled appropriately with contents, including concentrations and date the chemical or solution was generated. Chemicals should be stored according to the directions in their MSDS and according to the NFPA Rating. Each chemical must be labeled thoroughly enough, so that even a person who does not work in the lab can identify any chemical.

How to handle chemicals and biohazards

- Treat all chemicals as if they were hazardous until you learn otherwise.
- Label all containers with contents, including concentrations and date
- Wear gloves and goggles when handling potentially hazardous materials
- Read the label completely before opening a chemical bottle (pay special attention to warning labels).
- Open volatile organic solvents only in a laboratory fume hood.
- Close all containers immediately after using.
- Always handle chemicals with care to avoid spills.
- Report any spills of a potentially hazardous chemical immediately to your supervisor
- Always use clean glassware to prevent contamination.
- Don't pour unused chemicals back into storage containers where it may contaminate the rest of the reagent.
- Dispose of unused chemicals in proper waste containers. Do not flush chemicals or cleanup materials down the drain without instructor's consent.
- Clean up work areas thoroughly when you are finished. Always clean up shared areas such as balances and stir plates. Never leave spilled chemicals sitting on a balance, even if you did not spill it. They can corrode the instrument.
- Wash hands prior to leaving the laboratory.

5. **What is the proper way to dispose of chemicals and hazardous materials in the laboratory environment?**

The disposal of hazardous chemicals is subject to state and federal regulations, and is ultimately overseen by the Environmental Protection Agency (EPA). Treat all biological and chemical materials as if it were hazardous waste, unless notified otherwise. The appropriate disposal method depends on the type of waste materials. Solutions should not be washed down the drain unless they contain no chemical or biological hazards. All wastes should be disposed of in the proper labeled waste containers. Hazardous chemicals should be poured by funnel into a labeled chemical waste bottle. Biohazards should be placed into an autoclavable biohazard bag made of a high melting point plastic, sealed with autoclave tape, and autoclaved at high temperatures and pressures to completely kill any live organisms. Glass should go into a labeled glass disposal box.

6. **What is the purpose of a Standard Operating Procedure (SOP)?**

A Standard Operating Procedure (SOP) is a document that describes in a step-by-step outline form how to perform a particular task or operation. Everyone in an organization must follow the same procedures to assure that tasks are performed consistently and correctly. Most companies have a wide variety of SOPs that describe how to do different tasks. In many companies, technicians are trained in how to follow individual SOPs and their training record specifies which SOPs they are trained on and are authorized to use.

7. **What is the purpose of a Material Safety Data Sheets (MSDS)?**

A MSDS is a legally required technical document, provided by chemical suppliers, that describes the specific properties of a chemical. The MSDS should always be on file in the lab, and there are several web sites that offer MSDS databases. All MSDS are divided into the same 8 sections:

1. **Chemical identity.** The manufacturer's contact information is here, along with contacts for emergency situations.
2. **Hazard ingredients/identity.** Some chemicals have multiple components, and many single-component chemicals have alternative names. These are all listed here. Hazardous chemicals are also indicated.
3. **Physical chemical characteristics.** A list of physical properties states the general properties concerning the chemical, such as is the substance a solid or liquid and how volatile it is.
4. **Fire and explosion hazard data.**
5. **Reactivity data.** This information is essential in determining the proper handling and storage of chemicals. By knowing the reactivity patterns of a chemical, you know what substances or conditions from which you must isolate the chemical. For example, acids and bases react with each other, giving off large amounts of heat, which is why they should be stored separately from each other. Others react with water and should be stored in sealed containers with desiccants.
6. **Health hazards.** The best source of specific toxicology data is given here, such as symptoms of acute exposure and some recommended emergency procedures.
7. **Precautions for safe handling and use.** This describes how to deal with spills.
8. **Control measures.** Specific recommendations for personal protective equipment (PPE) are given here.

C. Essential Vocabulary

The following terms are essential vocabulary for mastery of the related standard.

- Environmental Protection Agency (EPA)
- Occupational Health and Safety Administration (OSHA)
- Right to Know
- Hazardous material
- Good laboratory Practices
- Standard Operating Procedures
- Material Safety Data Sheets (MSDS)
- Personal protective equipment (PPE)
- CFR1910.1450
- National Fire Protection Association (NFPA) Ratings
- Carcinogen
- Combustible
- Emergency
- Explosive
- Flammable
- Laboratory
- Fume hood
- Oxidizer
- Physical hazard
- Unstable (reactive)
- Water-reactive

D. Textbook Correlations for Biotechnology*: Science for the New Millennium*
The textbook does devote an extensive amount of the text to laboratory safety. However, there are several references to standard operating procedures (SOPs) throughout the text, which can be used for instruction.

E. Suggested Labs and Lessons

1. **Biotechnology: Science for the New Millennium** textbook

Activity 3.5 Writing a Standard Operating Procedure (SOP) Page 94

2. **Biotechnology Laboratory Manual**

Laboratory 1b Laboratory Safety: Protesting Yourself and Your Coworkers

3. **Other:**

On the next page, there is a worksheet that allows students to review the safety procedures and content covered in the laboratory/ classroom discussion. It will need to be modified to match your environment, but it as an effective, practical activity that gets students up and moving around in order to locate all the key lab elements and encourages as well as reviewing basic safety rules.

Biology Lab Safety Rules Worksheet and Information **Name: _____**

Part 1 Mapping the Laboratory

Draw a sketch of the laboratory and indicate the location of the following safety items:

eyewash stations	sinks
lab benches	fume hoods
fire extinguisher	windows
exits	fire blanket
emergency evacuation rally point (outside)	

Since you will be responsible for gathering materials you need for each lab exercise during the semester, you will need to know where these items are stored. If you are not familiar with an item or if you cannot find it, use the equipment & supply locator folder on the instructor's desk. After you locate them, please indicate their location on your laboratory sketch.

glassware	broken glass disposal
gloves	freezer (-20˚C)
hotplate/stirrers	refrigerator (4˚C)
micropipetters	37 ˚C incubators
micropipetter tips	tubes
microcentrifuges	microscopes
test tube racks	microcentrifuge tube racks
marking tape	Sharpie (permanent markers)

Part 2 Finding MSDS and Safety Information on the Internet

Use the Internet to search for chemical company websites, university departments, or other databases containing MSDS information. Locate information for the following 3 chemicals:

a. Nicotine, an addictive substance found in tobacco.
b. Ethidium bromide, a stain commonly used for marking DNA.
c. Sodium chloride, table salt.

For each, find the LD_{50} (oral, rat, mg/kg) and whether it is a mutagen or carcinogen.

Review the safety rules listed, and answer the following questions regarding the laboratory room.

Part 3. Safety Equipment and Information:

Information about chemicals used in this laboratory can be found in Material Safety Data Sheets (MSDSs) located _____

The emergency gas shut-off for this lab is located: _____
Shut off the gas immediately if gas nozzles or valves are damaged, or if there is a fire.

Fire extinguishers are located (1) _____

(2) _____

Fire blankets are located (1) _____

(2)_____

If you are on fire, stop, _____ and _____. Let someone else get the fire blanket.

An eyewash station is located _____

If a chemical is splashed or rubbed into your eyes, you must use the eyewash for at least _____ minutes. Put your face close to the basin with your eyes held open and press the lever to start the spray.

Dress code and personal protective equipment (PPE)

- While in the lab you must wear _____-toed shoes.
- In lab activities involving chemicals, you must wear _____ pants or skirts (below the _____) or a lab apron/coat (provided).
- You must wear _____ or safety _____ when directed to do so by the instructor or lab safety instructions.
- Wearing contact lenses in the lab is strongly discouraged. Students wearing _____ _____must wear safety goggles instead of safety glasses.
- You must tie back any long _____ in labs involving open _____, and it is recommended you do so for any lab.
- Gloves are provided and should be worn for any lab activity. Your instructor will inform you when gloves are _____ rather than optional.

Waste disposal

For chemical wastes, there are (i) flammable organic, (ii) inorganic, and (iii) organic waste containers located _____

For other wastes, there are containers for

- biohazards – located _____
- glass – located _____
- other trash – located _____

Lab conduct

DO NOT

- horse around or perform unauthorized experiments
- eat, drink, or chew (tobacco or gum)
- bring drinks or food (even in closed containers) into the lab
- pipet by mouth
- taste chemicals, or directly smell chemical fumes

You must follow all procedures in manuals, in handouts, and as given by the instructor.

F. General Tips and Misconceptions

Students generally take the safety aspects too lightly, and do not appreciate the importance of laboratory safety. As instructors, we have the responsibility to teach the students the appropriate manner to operate in a laboratory and hold them to a safe and professional standard. In most science classes, safety is not the focus of instruction, so students do not appreciate the gravity of its importance. It is advised that you spend a significant amount of time covering these standards and practices.

Standard Operating Procedures are also poorly understood by the students, and it requires several drafts for students to write an effective SOP. A great introductory activity for the SOP concept is to have the students write a SOP for a simple lab process, such as using a balance or measuring water in a graduated cylinder. Then take their SOPs up and pass them back out to different students, and see if the SOPs are accurate enough for another student to follow if they do only what the SOP states. Additionally, writing a SOP for the simple activity of making a sandwich is an excellent but challenging assignment.

TOP 10 Reasons to Have a SOP

1. To provide people with all the safety, health, environmental and operational information necessary to perform a job properly.
2. To ensure that security operations are performed consistently to maintain quality control
3. To ensure that business processes continue uninterrupted and are completed on schedule.
4. To ensure that no failures occur in manufacturing and other business processes that would harm anyone in the surrounding community.
5. To ensure that approved procedures are followed in compliance with company and government regulations.
6. To serve as a training document for teaching users about the process for which the SOP was written.
7. To serve as a checklist for co-workers who observe job performance to reinforce proper performance.
8. To serve as a checklist for auditors.
9. To serve as an historical record of the how, why and when of steps in an existing process, so there is a factual basis (not hear say) for revising those steps when a process or equipment is changed.
10. To serve as an explanation of steps in a process so they can be reviewed in accident investigations.

11
Biotechniques and Applications

A. GPS Standards for HS-IBT-4

B. Essential Questions and Answers

C. Essential Vocabulary

D. Textbook Correlations

E. Suggested Labs and Lessons

F. General tips and Misconceptions

A. HS-IBT-4. Students will demonstrate how concepts of physical science connect to biochemical applications and techniques.

a. Calculate and prepare buffers, stock solutions, and reagents.
b. Analyze and apply the concepts of homeostasis and molar relationships to biochemical reactions.
c. Draw conclusions regarding protein function and structure as it relates to the pH of a solution.
d. Analyze enzyme activity using assays for reactants and products.
e. Utilize electrophoresis, chromatography, microscopy and spectrophotometry to identify, separate and to draw conclusions about biological molecules.
f. Use antibody specificity for antigens to test for the presence of protein (e.g., ELISA, Western Blot, antibody staining).

B. Essential Questions and Answers:

1. What is a buffer?

A buffer is a solution that resists changes in pH when the hydrogen ion or hydroxide ion concentration is changed.

2. What are the most common ways of expressing concentration in the laboratory?

Mass/volume, % mass/ volume, a standard common amount referred to as "X" and molarity

3. How do physical conditions affect the structure and function of a protein?

Proteins are affected by a variety of environmental factors, such as temperature, pH, cofactors, and the concentration of molecules that bind to a protein (salts and minerals). As a protein's structure is affected by the external environment so is its activity. A classic example is the digestive enzyme pepsin, which requires the low pH of the stomach to remain active and catalyze the breakdown of proteins and polypeptides.

4. What is an enzyme? How can you measure its activity?

An enzyme is a protein that functions as a catalyst and thus works to speed up chemical reactions. Enzyme activity can be measured by the loss of initial reactants and/or the production of final reaction products.

5. What techniques are available for measuring cells and the major macromolecules?

There are numerous indicator molecules that change color or another property when in the presence of specific organic molecules.

6. What is the difference between an antigen and antibody?

An antigen is a protein or molecule that is targeted and bound by antibodies, yet an antibody is a protein produced by the immune system that recognizes and binds to a specific molecule with an extremely high affinity.

7. How does an antibody used to test for proteins?

Antibodies can be produced for a specific protein by injecting the protein of interest into an animal and collecting the antibodies (located in the blood plasma) produced by that animal against the protein.

C. Essential Vocabulary

The following terms are essential vocabulary for mastery of the related standard.

- Antibody
- Antigen
- Biochemistry
- Binding
- Buffer
- Chromatography
- ELISA
- Enzyme
- Homeostasis
- Microscopy
- Microliter
- Molar
- Mole
- Molecular weight
- pH
- Products
- Protein
- Reagent
- Reactants
- Solution
- spectrophotometer
- staining
- TE buffer
- TAE buffer
- UV260
- Western blot

D. Textbook Correlations for *Biotechnology: Science for the New Millennium*

E. Suggested Labs and Activities

The following labs are excellent for introducing the content and allowing students to explore it. Presenting the labs in the following order helps students to understand how the physical properties affect different biological molecules.

The labs in Chapter 2 of the manual help students to understand the range of biological molecules they will be studying and how they may be altered. These labs may be completed at the beginning of the unit to help students understand the subject. However, the content and labs in Chapter 3 introduces the essential chemistry concepts that must be mastered before moving forward because the chemical and laboratory concepts are foundational to the skills required. Thus, these labs are all considered essential and required to allow students to grasp the implications of chemistry in biotechnology.

After the basic chemistry concepts and basic laboratory skills are mastered, the labs in Chapters 5, 6, and 7 are completed more easily because the students are able to make solutions and perform assays. These labs clearly demonstrate how various physical factors affect molecules and at the same time allow them to be studied by laboratory workers. Through these experiences, students acquire the knowledge and skills of a biotechnician, yet this process requires a significant amount of classroom time to be devoted to the laboratory learning process.

F. General Tips and Misconceptions

Many students struggle with learning how to do the basic mathematical calculations and using the formulas to calculate dilutions and concentrations. Explicitly teaching the math skills and modeling of how to solve these problems helps students to acquire the skills required. This will need to be constantly assessed and reviewed throughout the school year.

Given the practical nature and skill-based components of this standard, many aspects of this standard are best measured by informal assessment during the unit and formally at the end of the period. Students should be given multiple opportunities to master these skills during formative assessment. With a simple clip board and assessment sheet, the teacher can randomly check the students' progress during laboratory work and normal assignments. If the student masters the skill or standard being assessed, the teacher can then document the achievement. By displaying their skills and knowledge, students are given the opportunity to demonstrate practical mastery of the standard and acquire real-life skills.

With respect to the final assessment, Lab 5b is an excellent activity for both an instructional activity and summative assessment. If done initially during the instructional period, the students can repeat the lab as a final performance exam for the unit or semester. To use the lab as a summative assessment, students are informed that they will be challenged with modifying the lab and evaluated based upon the quantity of juice that they produce. The students can then be allowed to alter any variables in the experiment in order to produce a maximal juice amount. However, students should base the experimental design upon solid research or experimentation. For evaluation, the teacher can grade the modified experimental introduction and procedure to check for understanding and appropriate experimental design. Alternatively, the teacher could use the laboratory conclusion and juice quantity for the student's evaluation.

12
Genetic Engineering

A. HS-IBT-6. Students will demonstrate how manipulation of nucleic acids through genetic engineering (recombinant DNA and RNA technologies) alters the function of proteins and subsequent cellular processes.

a. Describe the function of DNA, RNA, and protein in living cells and the Central Dogma.

b. Demonstrate how the structure of DNA influences its function, analysis, and manipulation.

- Isolate genomic and recombinant DNA from cells and solutions and analyze its purity and concentration.
- Explain and demonstrate the principles involved in DNA analysis via agarose gel electrophoresis.
- Describe previous and current DNA sequencing technologies.

c. Explain the role of enzymes (e.g., restriction enzymes, DNA polymerases, and nucleases) in the production and manipulation of DNA molecules.

d. Determine and analyze the effect of qualitative and quantitative changes of specific proteins on cell function.

B. Essential Questions and Answers:

1. **What is the central dogma?**

The Central Dogma of Biology states that DNA codes for RNA and that RNA codes for proteins. These proteins are responsible for the traits and phenotype of the cells.
DNA > RNA > PROTEIN > TRAIT

2. **What is DNA sequencing?**

DNA sequencing is a process used to find the nucleotide base sequence in pieces of DNA. A complementary DNA strand is made using a small proportion of fluorescently labeled nucleotides, which stops the replication process. The DNA is then separated using electrophoresis and the DNA sequence can be read from the gel. It is generally an automated process in labs presently. It has been used in the Human Genome Project and is used to identify genes responsible for genetic disorders such as Alzheimer's disease.

3. **How are DNA and RNA different?**

All nucleic acids are composed of nucleotides which have three parts: a simple sugar, a phosphate group, and a nitrogen base. In DNA (deoxyribonucleic acid), the simple sugar is deoxyribose. In DNA, there are four possible nitrogen bases: adenine, thymine, cytosine, and guanine. DNA is composed of two strands of nucleotides twisted together in a shape called a double helix. RNA is also a nucleic acid. It differs from DNA structurally in three ways. First, RNA is single stranded while DNA is double stranded. The second difference is that the sugar in RNA is ribose. The third difference involves the nitrogen bases. RNA does not contain thymine; it contains uracil. There is also a difference in their roles and locations. DNA contains the instructions for protein synthesis and remains in the nucleus. RNA takes the instructions from the nucleus to the ribosomes and is involved in the synthesis of proteins.

4. **How are enzymes involved in DNA replication?**

DNA cannot leave the nucleus of the cell where it is stored because it is too large to pass through the pores of the nuclear membrane. During replication, enzymes "unzip" the two strands of the DNA molecule by breaking the hydrogen bonds that hold the base pairs together. Each strand serves as a template for the attachment of complementary bases. Then, another enzyme zips up the two new DNA molecules. The two new molecules are identical, each containing one of the parent strands and one newly made daughter strand. When the cell replicates, the nuclear membrane disintegrates and each new daughter cell receives an identical copy of the parent cell's DNA.

5. **What is PCR?**

Polymerase chain reaction is a process used to make multiple copies of genes. Using primers to start the replication process, DNA is heated to separate the 2 strands. It is then cooled to

allow the replication process. This process is repeated for multiple copies. In forensics, it has been used to amplify the amount of DNA found at a crime scene. In medicine, it has been used to simplify the DNA from a single embryonic cell for rapid diagnosis of genetic disorders. It is also used to identify infective agents and genes that cause disorders such as hemophilia and cystic fibrosis.

6. What is gel electrophoresis?

Gel electrophoresis is a procedure used to separate and analyze DNA fragments. A mixture of DNA fragments are placed at the end of a porous gel and an electrical voltage is applied to the gel to separate the fragments. DNA fingerprinting has been used to determine paternity and to identify the DNA at crime scenes.

7. How is the DNA code transferred to the ribosome for protein synthesis?

Proteins are synthesized at the ribosomes, from the DNA code, but since DNA is stored in the nucleus, a message with the DNA's code is transcribed and sent instead. During transcription an enzyme bind to a promoter site and "unzips" the two strands of the DNA molecule by breaking the hydrogen bonds that hold the base pairs together. One strand serves a template for the attachment of complementary bases. However, not all the DNA is transcribed; just the instructions for the protein that is being synthesized. The single stranded copy of the DNA called messenger RNA (mRNA) exits the nucleus through the pores in the nuclear membrane and makes its way to the ribosome. mRNA is constructed of nucleotides just as DNA is except the base uracil is used instead of the base thymine.

8. What is the role of DNA in gene expression?

An expressed gene is a gene that has been transcribed into RNA. Only a fraction of the genes in a cell are expressed at any given time. Certain DNA sequences serve as promoters and binding sites for the RNA polymerase (enzyme). Regulation of gene expression is important in shaping the way a complex organism or even a simple cell controls its function.

9. How are proteins synthesized?

The mRNA strand serves as the instructions for the sequence of amino acids that make the protein. Each three base sequence of mRNA is called a codon. Each codon specifies a particular amino acid. A transfer RNA (tRNA) molecule "transfers" the specified amino acid from the cytoplasm to the ribosome. Because tRNA molecules have the complementary bases to the codon (called an anti codon) on one end of it, they can bind with the mRNA codons. The other end of the molecule carries the amino acid that is specified by the codon. The next amino acid is brought by another tRNA molecule and as the tRNA anti-codons bind with the codons on the mRNA the amino acids are bonded to each other forming the protein chain. When a stop codon is reached, the protein is released and coils up in the structure that will allow it to perform its function.

C. Essential Vocabulary

The following terms are essential vocabulary for mastery of the related standard.

- Agarose
- Amplification
- Annealing
- Antiparellel
- Alcohol precipitation
- Base pair
- BLAST
- Buffer
- Chromosome
- Central dogma
- Codon
- Competency
- Cystic fibrosis
- DNA
- dNTP
- Double helix
- Ethidium bromide
- Exon
- Genome
- Gel electrophoresis
- Genetic engineering
- Gene therapy
- Genotype
- Green Fluorescent Protein
- Helicase
- Hybridization
- Hydrogen bond
- Human Genome Project
- Intron
- Loading dye
- Lysis
- Lysozyme
- Methylene blue
- Microarray
- Maxiprep
- Midiprep
- Miniprep
- Mutagenesis
- Nitrogenous base
- Nucleic acids
- Nucleases
- Nucleotide
- Phenotype
- Phosphate group
- Phosphodiester bond
- Physiology
- Polyacrylamide
- Polymerase
- Primer
- Primer annealing
- Primer extension
- Probes
- Protease
- Proteins
- Purine
- Pyrimidine
- Recombinant DNA
- Restriction fragments
- Restriction Fragment Length polymorphisms
- RNA
- RNase
- RNA polymerase
- Sanger Method
- Selection
- Semi-conservative replication
- Sequencing
- Sickle cell anemia
- Spectrophotometer
- Stain
- Supernatant
- Template
- Thermal cycler
- Topoisomerase
- Transcription
- Transcription factors
- Transduction
- Transformation
- Translation
- Vector
- adenine
- cytosine
- guanine
- thymine

D. Textbook Correlations for *Biotechnology: Science for the New Millennium*

E. Suggested Labs and Activities

Biotechnology Laboratory Manual

The selected labs demonstrate the extraction and analysis of DNA (labs 4a-4j) and protein (5e-5f) via electrophoresis. Generally speaking, the process of extraction and analysis via electrophoresis is divided into several steps: 1) making solutions; 2) extracting the molecules of interest; 3) preparing samples for analysis,; 4) separation via gel electrophoresis,; and 5) staining the gel. Each step takes approximately one 5o minute period. Therefore, the process of extraction and analysis, from beginning to end, takes a week of class time. The three labs proposed here will take three weeks to complete. One week for the initial analysis of DNA in Chapter 4, and one weeks each to complete the PAGE analysis of proteins (Chapter 5) and human PCR lab (Chapter 13). The suggested pacing completes the Labs in Chapter 4 and 5 first semester and completing Labs 13e-13g early second semester.

It is also important to note that these labs require careful planning of resources and materials. Teachers will need to purchase the primers for PCR Genotyping in order to complete the Labs in Chapter 13.

Lab	Title	Page
4a	Making Solutions for DNA Isolation	64
4b	Pulling DNA out of Solutions: DNA Spooling	65
4c	Testing for the Presence of DNA, RNA, and Protein in DNA Extracts	68
4i	Making Agarose Gels for Separating and Analyzing DNA Fragments	82
4j	Using Gel Electrophoresis to Study DNA Molecules	85
5e	Preparing Proteins for Analysis by Vertical Gel Electrophoresis	99
5f	Characterization of Proteins by PAGE	101
13e	Using PCR to amplify Regions of Lambda Phage DNA	247
13f	Extracting DNA from Human Cells for PCR and Sequencing	250
13g	DNA Typing by PCR-Genotype: Determination of an Alu Insert	251

Content Rich Activity:

The following activity uses a “real-world” application of DNA technology to solve a problem, a crop disease. Restriction enzymes cut DNA to produce fragments of different lengths. In order to sort these fragments according to their sizes, a technique known as gel electrophoresis is used. The gel through which the DNA moves is made of agarose, a seaweed derivative. Using this technology, a DNA fingerprint can be produced and the size of DNA samples can be calculated by adding the size of all the individual pieces together. This activity is an excellent review or introduction to gel electrophoresis and entirely paper based, so it requires minimal resources.

Analysis of Wheat Germ "Germs"

Great Gatsby of Digestion!!! The FDA (Fiber Diet Association) has just issued a recall of non-genetically modified wheat germ. A new plant disease has infected most of the country's wheat germ and could affect other crops. Luckily, many crops have been genetically modified to have resistance to similar diseases, but few batches of wheat germ are actually resistant. **You goal is analyze samples of wheat germ DNA samples from the previous lab to determine which samples might be infected.** The only question is how????

You seem to remember something about restriction enzymes from your awesome biology class. Restriction enzymes are enzymes that cut DNA at specific locations. Bacteria naturally have restriction enzymes that break down the foreign DNA of invading viruses. These enzymes are useful in "**cutting**" DNA into fragments. For example, examine the results below as the restriction enzyme EcoRI makes staggered cuts at specific sites along this strand of DNA:

5′ A T G A A T T C T T T G A A T T C C T C T 3′
3′ T A C T T A A G A A A C T T A A G G A G A 5′

5′ A T G	A A T T C T T T G	A A T T C C T C T 3′
3′ T A C T T A A	G A A A C T T A A	G G A G A 5′

PRE_LAB QUESTIONS

1. The number of fragments of DNA that result from those cuts is _____.

2. What do we call the enzyme that cuts the DNA?

3. We can express the DNA fragments as the number of base pairs in each fragment. How many base pairs (bp) are found in the smaller fragment?

4. Do you think restriction enzymes could be used to cut DNA from organisms other than humans, like wheat germ? Explain.

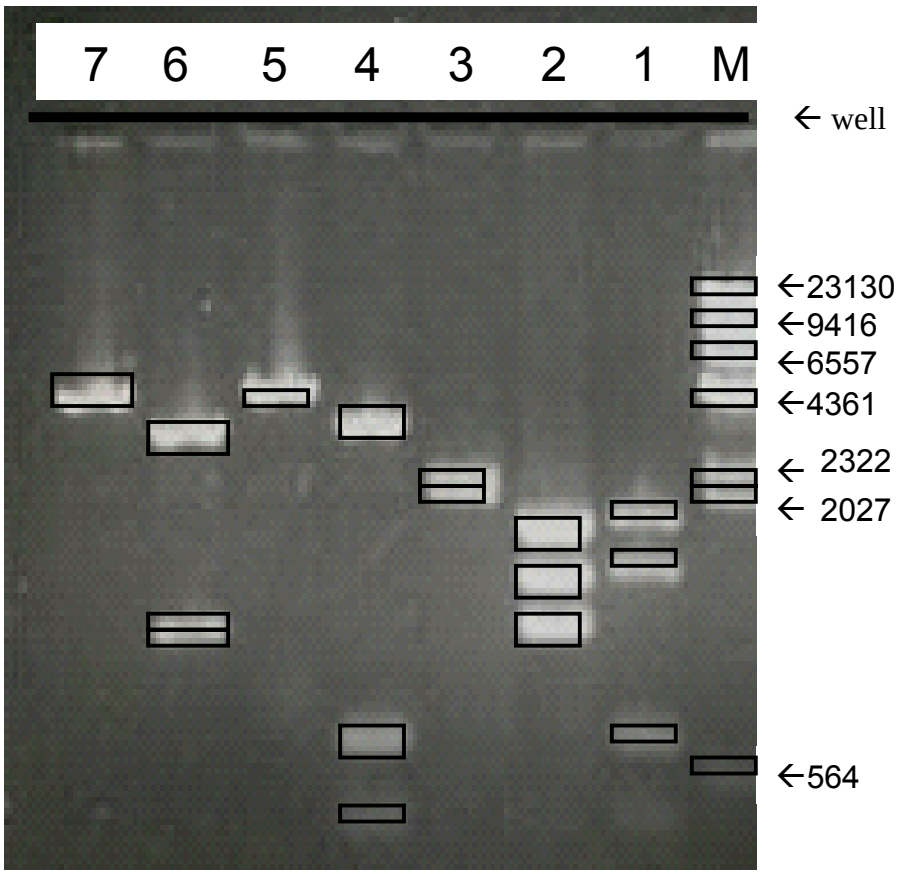
Using restriction enzymes, the you and your team cut the DNA isolated from the wheat germ and then separate the cut pieces using DNA electrophoresis. The virus is about 4200 nucleotide base pairs (bp) in size, and infected samples will have three DNA fragments that sum together in the range of 4000-4500 base pairs and resistant samples will have 2 bands or less visible on the gel.

Gel Analysis Instructions:

1. On the next page is a gel photo of a gel with 7 samples of wheat germ DNA from the previous lab cut with restriction enzymes (lanes 1-7) and a DNA size standard (lane M) to help you determine the size of the fragments in lanes 1-7. Gel electrophoresis separates DNA based upon size, such that smaller pieces move farther in the gel.
2. Starting with lane M (far right), measure the distance from the well (the line across the top of the gel) to each DNA band in the DNA standard marker (bright spots with the box drawn over it) migrated on the gel (in mm).
3. Each of the bands in the M column is of a known size (# of bp on the right of the page). Write in the distance traveled for each band next to the correct fragment size in the chart below.
4. Use the semi-log graph paper on the next page to construct a line graph that shows DNA fragment size (in bp) compared to distance traveled on the gel (in mm).
5. Measure the bands in well columns 1-7 and write the distance traveled (in mm) for each band marked with a box and record in the chart below.
6. Use the standard curve created in step 4 to estimate the size of the DNA fragments for lanes 1-7 and then use this info to determine which samples might be infected.

HINT: The virus is about 4200 nucleotide base pairs (bp) in size, and infected samples will have three DNA fragments that sum together in the range of 4000-4500 base pairs and resistant samples will have 2 bands or less visible on the gel.

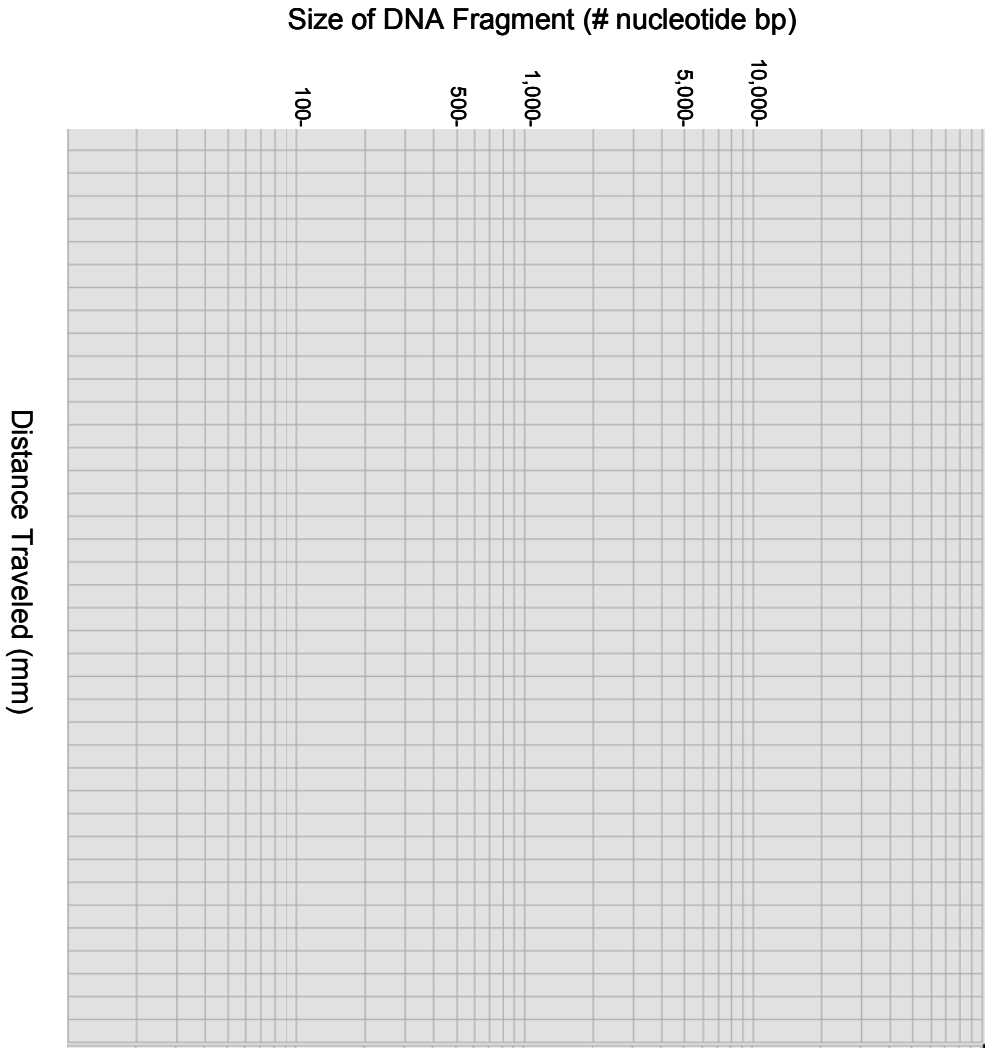
Gel picture



DATA CHART

Lambda HindIII digest bp size (standard)	Dist. Migrated in mm	Band #	Lane 1 (3 DNA bands)	Lane 2 (3 DNA bands)	Lane 3 (2 DNA bands)	Lane 4 (3 DNA bands)	Lane 5 (1 DNA bands)	Lane 6 (3 DNA bands)	Lane 7 (1 DNA bands)
23,130 bps		1							
9416		2							
6557		3							
4361		4							
2322		5							
2027		6							
564		7							

Graph



QUESTIONS

1. What is dependent variable in this experiment? Independent variable?

2. How does the size of the DNA affect the distance traveled on the gel?

3. Which samples are infected? Uninfected?

4. Genetic engineering made some of samples resistant the wheat germ "germ." Name three other specific examples of how genetic engineering has impacted our lives.

5. How do feel about genetic engineering of plants? Medicine? Animal

TEACHER INSTRUCTIONS

This activity uses a "real-world" application of DNA technology to solve a problem, a crop disease. Restriction enzymes cut DNA to produce fragments of different lengths. In order to sort these fragments according to their sizes, a technique known as **gel electrophoresis** is used. The gel through which the DNA moves is made of **agarose**, a seaweed derivative. Using this technology, a DNA fingerprint can be produced and the size of DNA samples can be calculated by adding the size of all the individual pieces together.

First, students will measure how various samples of DNA migrate on the pictured gel and record the distance traveled of each of these DNA fragments. Using the DNA size standard marker (lane M), students will measure and graph DNA fragment size (base pairs) versus distance traveled (mm) for this sample. Students should measure from the wells to the leading edge of the band (the edge farthest from the well). The bands have been outlined with boxes to make them easier for the students to identify. The students will then be able to use the standard curve to determine the size of the unknown fragments in lanes 1-7. Below are keys terms and definitions to be considered for this lesson. Lastly, a key for the measurements and questions are listed.

KEY TERMS TO BE CONSIDERED FOR THE LESSON

- **DNA fragments** — DNA segments resulting when DNA is cut with a restriction enzyme. Fragments of different sizes (lengths) are produced.

- **DNA restriction analysis** — used to help further our knowledge about the structure of DNA, for mapping and sequencing DNA, and also for DNA typing for identification purposes. Restriction analysis has three parts: DNA digesting, electrophoresis, and staining plus analysis. DNA fingerprinting utilizes DNA restriction analysis.

- **Gel electrophoresis** — the process that uses gels made of agarose or some other polymer to separate DNA fragments or proteins by size, charge, or shape using electricity to move the electrically charged molecules through the gel. As the DNA moves through the tangled pores of the agarose fibers, the smaller pieces move faster and the larger pieces more slowly.

- **Gel lanes** — the paths the molecules travel through the gel from the wells to the opposite end of the gel.

- **Restriction digest** — the process of using any of the restriction enzymes that cut nucleic acids at specific restriction sites to produce fragments which are then known as restriction fragments.

- **Restriction enzymes** — (restriction endonucleases) enzymes that act as "enzyme scissors" to cut the DNA at a specific sequence (palindromic sequence) of nucleotides.

- **Restriction site** — the specific sequence of nucleotides (palindromic sequence) that the restriction enzyme recognizes and "cuts" resulting in DNA fragments of different sizes.

- **Wells** — the small, cup-like structures or indentations left in the agarose gel when the comb is removed. These wells will be filled with DNA or protein prior to electrophoresis.

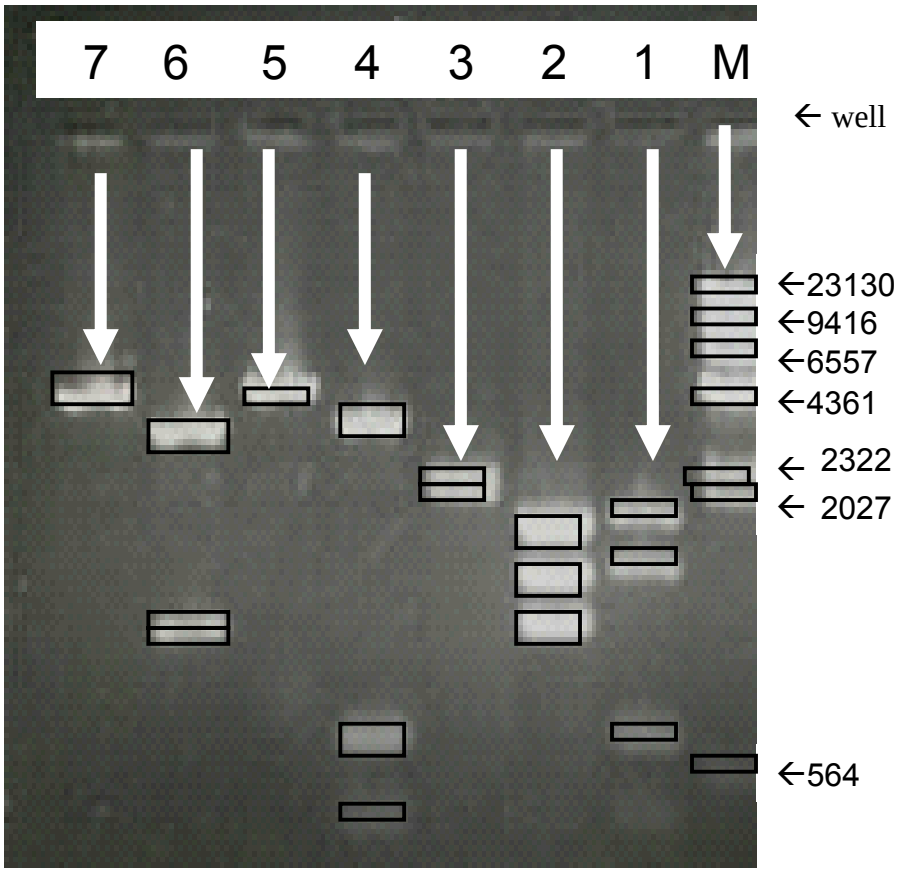
KEY

PRE_LAB QUESTIONS

1. The number of fragments of DNA that result from those cuts is 3.
2. What do we call the enzyme that cuts the DNA? Restriction Enzymes
3. We can express the DNA fragments as the number of base pairs in each fragment. How many base pairs (bp) are found in the right most fragment? Four

5. Do you think restriction enzymes could be used to cut DNA from organisms other than humans, like wheat germ? Explain.

Yes, restriction enzymes could be used to cut DNA from other organisms. In fact, restriction enzymes can be used to develop a DNA fingerprint.



DATA CHART

DNA standard bp length	Dist. Migrated in mm	Lane 1 (3 DNA bands)	Lane 2 (3 DNA bands)	Lane 3 (2 DNA bands)	Lane 4 (3 DNA bands)	Lane 5 (1 DNA bands)	Lane 6 (3 DNA bands)	Lane 7 (1 DNA bands)
23,130 bps	21	52	56	48	41	35	42	35
9416	25	59	63	50	84		65	
6557	29	82	69		92		68	
4361	35							
2322	48							
2027	50							
564	86							

QUESTIONS

1. What is dependent variable in this experiment? distance traveled in the gel
   Independent variable? Size of the base pair fragment

2. How does the size of the DNA affect the distance traveled on the gel?
   Fragment size is inversely related to the distance traveled on the gel. Therefore, smaller DNA fragments travel farther on the gel, while larger DNA fragments travels shorter distances on the gel.

3. Which samples are infected? Samples 1 & 2
   Uninfected? Samples 3-7

4. Genetic engineering made some of samples resistant the wheat germ "germ." Name three other specific examples of how genetic engineering has impacted our lives.

5. How do feel about genetic engineering of plants? Medicine? Animals?

F. General Tips and Misconceptions

The analysis of DNA via gel electrophoresis is a challenging experience for students. The actual experiment is a novel method for the students, so instead of appreciating the lab and learning from the experience, students are challenged just to be able to complete the procedure, which limits their learning. To assist students, the concept of gel electrophoresis should be introduced well in class and can be simulated/ modeled via electrolysis and using charged dyes in an agarose gel. The analysis of dyes with gel electrophoresis allows students to practice loading a sample into a well, working with the apparatus, and the interpretation of the results. If students can be made comfortable working with the electrophoresis apparatus as well as comfortable working with small volumes using a micropipettor before this lab, student learning is positively impacted. Additionally, online electrophoresis labs and paper based exercises, like the one in the previous section, help students to understand the laboratory processes better prior to conducting the experiment. Virtual electrophoresis labs can be found at the following addresses:

- http://www.scq.ubc.ca/files/VirtualLabDNA/vlabFrame.html
- http://learn.genetics.utah.edu/content/labs/gel/

After the students understand the electrophoresis process, they can begin to apply that knowledge to the analysis of DNA molecules. The restriction digest of Lambda phage DNA is a straight-forward and well established lab for this goal. Here are some helpful tips for you and your students when working with restriction enzymes.

Working with Restriction Enzymes

- Restriction enzymes are extremely sensitive to temperature changes and difficult to pipet.
- Do not allow students to work with the enzyme stock tubes until you are satisfied with their skills.
- During labs storing enzymes in ice filled Styrofoam cups are an inexpensive alternative to large ice buckets
- Restriction enzymes in solution are to always be store in the -20 C freezer and never held inside the hand but only by the fingertips.
- Master Mixes (Enzyme mixtures including everything but the DNA sample) can be made by the teacher at a 2x concentration, aliquotted to each lab group, and then diluted by students with the addition of an equal amount of DNA.
- When pipetting enzymes avoid bubbles! Do not pipet the solution up and down to mix.
- Mix in the enzyme by stirring the solution with the micropipette and tip used to add the enzyme
- Several suppliers sell dehydrated restriction enzymes that can be stored at room temperature until rehydrated. This is extremely convenient to keep in mind when ordering restriction enzymes.

13
Organisms in Biotechnology

A. HS-IBT-5. Students will compare and contrast common organisms used in biotechnology and relate the manipulation of living organisms to product and procedure development.

a. Distinguish between prokaryotic cells, eukaryotic cells, and non-living entities such as viruses.
b. Describe the characteristics and life cycles of model organisms used in biotechnology, including bacteria (e.g., E. coli), fungi (e.g., yeasts and Aspergillus), and animals (e.g., C. elegans, fruit flies, and rodents).
c. Monitor how environmental factors affect the growth of cells and model organisms in the laboratory.
d. Apply the basic concepts of cell growth to manipulate cultures under aseptic conditions in the laboratory.
e. Perform transformations, including competency, selection, antibiotic resistance, and analysis of transformation efficiency.

B. Essential Questions and Answers:

1. **What are the primary differences between prokaryotes and eukaryotes?**

Prokaryotes are organisms without a cell nucleus or other membrane-bound organelles. Prokaryotes are usually unicellular but in some rare cases are multicellular. Are organisms with membrane bound-nuclei and may be either unicellular or multicellular..

2. **What are some of the common model organisms used in biotechnology research?**

Mammalian models:

Mouse
Rat

Non-mammalian Models:

Arabidopis (plant)
C. elegans (round worm)
Daphnia (water flea)
D. melanogaster (fruit fly)
D. rerio (zebrafish)
E. coli (bacteria)
S. cerevisiae (budding yeast)
S. pombe (fission yeast)

3. **What are the environmental factors that affect the growth of cells?**

Temperature, pH, oxygen, and nutrients (sugars, lipids, and essential amino acids) can all influence cell growth in the laboratory and all cells have optimal culture conditions that promote the desired growth.

4. **What is aseptic technique?**

Aseptic technique is a set of specific practices and procedures which are performed under carefully controlled environmental conditions with the goal of minimizing contamination by or the spread of undesired organisms or molecules that would alter the life processes of the experimental

5. **Describe the process of transformation and how transformants are selected for?**

When cells take up foreign DNA and express the genes, the cells are said to be transformed. Transformation is a basic technique that is used frequently in most biotech laboratories. Usually, the goal is to introduce a foreign segment of DNA into bacteria and to use the bacteria to amplify the DNA in order to make large quantities of either the DNA or a protein encoded by the DNA. Bacteria are naturally transformed by plasmids, which are rings of DNA that contain 5-10 genes. Thus, the natural function of a plasmid is to transfer genetic information into bacteria. Many of the plasmids used encode resistance to an antibiotic via a resistance gene, so any transformed bacteria are able to survive exposure to an antibiotic that would normally kill them. Therefore, lab workers can grow bacteria that have been transformed with a specific plasmid in the presence of an antibiotic and know that any surviving bacterial cells have antibiotic resistance and therefore the plasmid.

C. Essential Vocabulary

The following terms are essential vocabulary for mastery of the related standard.

- Aseptic
- Aerobic
- Anaerobic
- Antibiotic resistance
- Aspergillus
- Bacteria
- *Caenorhabditis elegans (C. elegans)*
- Cell
- Competency
- Drosophilia melagaster
- E coli
- electroporation
- Eukaryote
- Exponential growth
- Growth rate
- Heat schock
- Incubator
- Media
- Mitosis
- Model organism
- Nucleus
- Prokaryote
- Selection
- Transfection
- Transformation
- Yeast
- Virus

D. Textbook Correlations for *Biotechnology: Science for the New Millennium*

E. Suggested Labs and Activities

Biotechnology Laboratory Manual

These labs allow students to work with and learn about cell biology and how cells are used in research and production of biotech products. The labs in Chapter 2 of the laboratory manual are excellent for introducing students to cells and model organisms. The students find Laboratory 2d particularly challenging and reward students, that able to best measure the cells.

Lab	Title	Page
2b	The Characteristics of Model Organism	17
2c	Using a Compound Microscope to Study Cells	22
2d	Making Microscope Measurements	25

Lab	Title	Page
4e	Making Media for Bacteria Cell Culture	71
4f	Sterile Technique and Pouring Plates	74
4g	Bacteria Cell Culture	76
4h	DNA Extraction from Bacteria	79
8c	Transformation of E. coli with pAmylase	153
8d	Growing and Monitoring Bacterial Cultures	156
8e	Scaling-Up E. coli Cultures for Amylase Production	159

Other Ideas

The NIH has an excellent website focused on model organisms and the policies that regulate their use in research. (http://www.nih.gov/science/models/)

The Venn Diagram labeled “Prokaryote Cells” and “Eukaryote Cells” on the next page helps students to organize their knowledge of basic features of the two major classes of cells and is used as either introductory activity or summarizing activity before assessing the students.

F. General Tips and Misconceptions

An alternative to the Biotechnology Laboratory Manual experiments are the kits available from many science education suppliers. A biotechnology-level series of kit is the Bio-Rad Explorer series. With regards to the Introduction to Biotechnology course, the most relevant and easy to use kits are the kits that utilize Bio-Rad's pGLO plasmid, encoding a green fluorescent protein (GFP). This series is able to introduce students to bacterial transformation, cloning, protein chromatography, and electrophoresis.

Beginning with the pGlo Bacterial Transformation Kit, students are able to understand transformation and bacterial cell growth. While recommended for a class of 32 students, this kit provides enough resources and materials for 40-50 students, or two class periods, if managed carefully. As long as the lab has the appropriate bacterial cell culture resources, the plasmid DNA and *E. coli* are sufficient for more students. This kit flows nicely into either the Chromatography Kit or the SDS-PAGE analysis of the GFP. While it is not necessary to purchase the kit for the SDS-PAGE, since most proteins can be examined quite

easily via SDS-PAGE, the Bio-Rad chromatography kit is recommended if one is attempting to purify the GFP via chromatography.

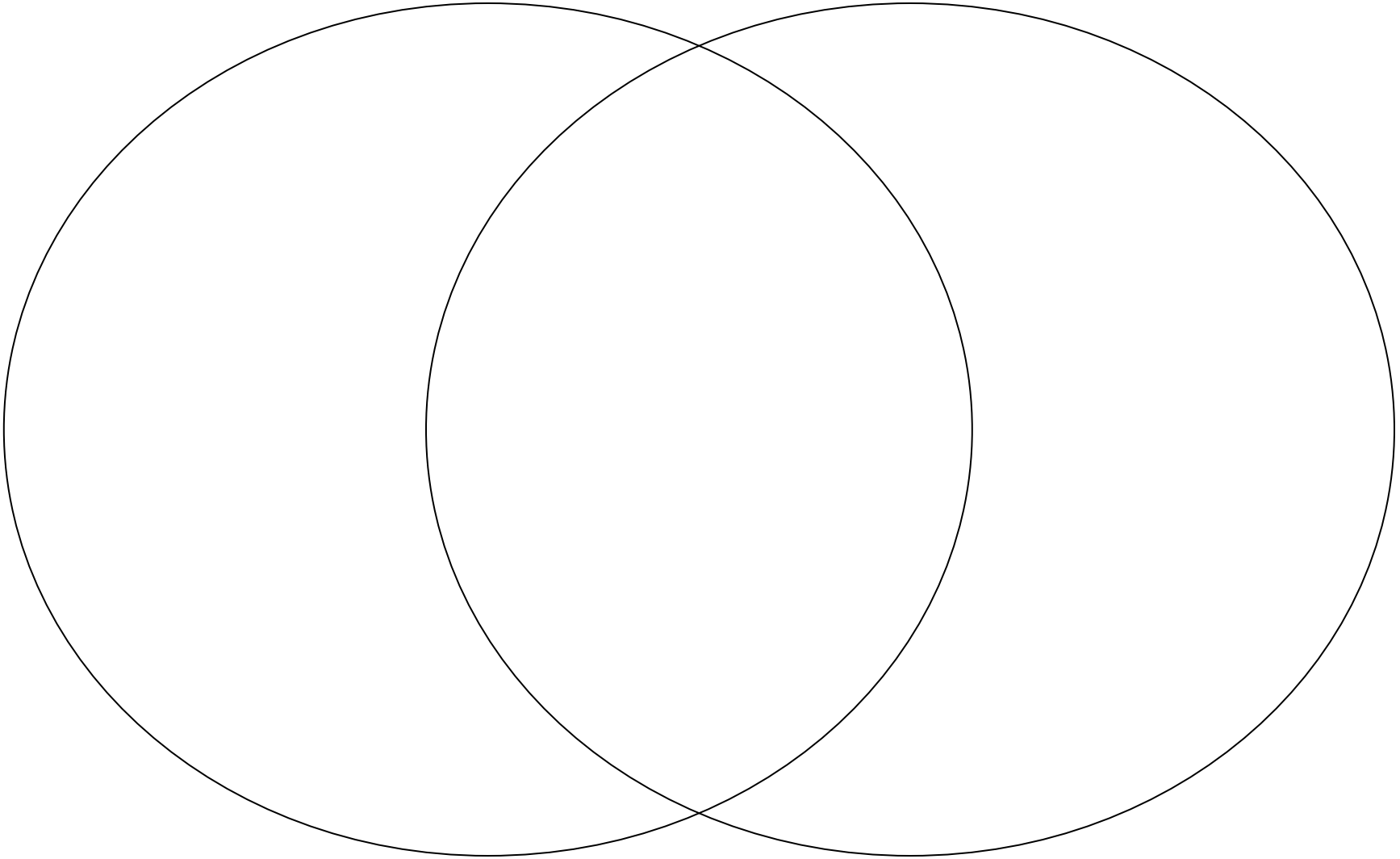
The recommended kits in this series are explained below. These kits have been used by the author and are useful for teaching the Introductory to Biotechnology standards. In Georgia

1. **pGLO Bacterial Transformation Kit**
   In this activity, students transform bacteria by introducing a gene, GFP, from the bioluminescent jellyfish *Aequorea victoria*. The pGlo plasmid allows for easy visualization of the GFP gene, and it is also effective in teaching transcriptional regulation.

2. **Green Fluorescent Protein Chromatography Kit**
   This kit guides students through the process of creating a new Biotechnology product — from discovery in the laboratory to biomanufacturing to market. It provides students with the opportunity to produce and purify a recombinant DNA product, which is a foundational process of modern biotechnology.

Prokaryote

Eukaryote



Complete the Venn Diagram comparing and contrasting prokaryotic and eukaryotic cells.

Appendix A: Recipes for Standard Biotech Lab Solutions

A. 1M Tris

- 121.1 g. Tris base
- 800 ml. ddH_2O
- Adjust the pH to the desired value by adding concentrated HCl.

pH	HCl
7.4	70 ml
7.6	60 ml
8.0	42 ml

- Allow the solution to cool to room temperature before making final adjustments to the pH. Adjust the volume of the solution to 1 liter with H_2O. Aliquot into containers and sterilize by autoclaving.

Comments: If the 1 M solution has a yellow color, discard it and obtain a better quality Tris. Although many types of pH electrodes do not accurately measure the pH of Tris solutions, suitable electrodes can be obtained from most manufacturers. The pH of Tris solutions is temperature-dependent and decreases approximately 0.03 pH units for each 1oC increase in temperature. For example, a 0.05 M solution has pH values of 9.5, 8.9, and 8.6 at 5° C, 25° C, and 37° C respectively.

B. TE Buffer (pH 8.0)

		Final Concentration
• 2 ml	1M Tris HCl (pH 8.0)	(10 mM)
• 0.4 ml	0.5M EDTA (pH 8.0)	(1 mM)
• 200 ml	ddH_2O	

C. 1%Agarose

- 1 g. agarose
- 100ml. 1X TAE Buffer

Mix into the agarose in the TAE for 1-2 minutes at room temperature to hydrate the agarose. Heat to near boiling to dissolve the agarose into the TAE. The agarose solution can be stored at 65o C in a liquid form, but at room temperature, the mixture is a solid. Therefore, when pouring a gel, one must work quickly and carefully to dissolve the agarose and pour into the gel form before it solidifies. Keeping a 65o C water bath and making the agarose in bulk keeps students from having to heat the solution to near boiling.

D. 10% SDS (**S**odium **D**odecyl **S**ulfate is also known as sodium lauryl sulfate)

- 100 g. SDS (eletrophoresis-grade)
- 900 ml ddH_2O
- Mix and heat to 68°C to dissolve. Adjust the pH to 7.02 by adding a few drops of concentrated HCl. Adjust the volume to l liter with ddH_2O. Aliquot into containers.

- The disodium salt of EDTA will not go into solution until the pH of the solution is adjusted to approximately 8.0 by the addition of NaOH.

Comments: Wear a mask when weighing SDS because SDS granules disperse easily and wipe down the weighing area and balance after use, Does not need autoclaving.

0.5M EDTA (pH 8.0)

- 186.1 g. Disodium ethylenediaminetetraacetate·$2H_2O$
- 800ml ddH_2O
- Stir vigorously on a magnetic stirrer. Adjust the pH to 8.0 with NaOH (~20 g of NaOH pellets). Aliquot and sterilize by autoclaving.

E. Lysis Buffer

		Final Concentration
• 20 ml	10% SDS	(1%)
• 2 ml	IM Tris · HCl (pH 8.0)	(10mM)
• 4 ml	0.5M EDTA (pH8.0)	(10mM)
• 5.84 g	NaCl	(0.5M)

- Bring up to 200ml with ddH_2O. Dispense into bottles.

F. 5X Tris- borate (TBE)

- 54 g Tris Base (or Sigma 7-9)
- 27.5 g. Boric acid
- 20 ml. 0.5M EDTA (pH 8.0)
- 800 ml ddH_2O
- Stir to get into solution. Bring up to 1 liter with ddH_2O. Does not need to be autoclaved. Remove stir bar.

G. 50X Tris-acetate (TAE)

- 242 g. Tris Base
- 57.1 ml Glacial acetic acid
- 100 ml 0.5M EDTA (pH 8.0)
- 1000 ml ddH_2O

H. Tracking Dye for Electrophoresis

- 0.25% bromophenol blue
- 40% (w/v) sucrose in water

Appendix B: Online Biotechnology Resources

Access Excellence **www.accessexcellence.org**
A series of learning modules on multiple science and health topics, including biotech and genetics. Sponsored by the National Health Museum, a non-profit organization founded by former U.S. Surgeon General C. Everett Koop. The "About Biotech" section of the site includes topics: Issues and Ethics, Biotech Applied, Careers, Graphics Gallery, and Biotech Chronicles.

Bio-Rad Destiny Science Curriculum Modules Destiny Modules
Five Curriculum Modules that align Bio-Rad educational kits with North Carolina Science Standards. Excellent lesson plans and support materials available as a pdf files.

Current Topics in Genome Analysis **www.genome.gov/12514286**
A lecture series covering contemporary areas in genomics and bioinformatics.

Genome Sciences Outreach Project **http://chroma.gs.washington.edu/outreach**
Innovative programs that bring laboratory science and materials to K-12 students and teachers. Directed by the Department of Genome Sciences at the University of Washington in Seattle, Wash.

Diving into the Gene Pool **www.exploratorium.edu/genepool/genepool_home.html**
An online exhibition exploring genetics and the Human Genome Project from a variety of perspectives. Produced by the Exploratorium, San Francisco, Calif.

The DNA Files **www.dnafiles.org/**
A series of 14 one-hour public radio documentaries and related information.

DNA from the Beginning **www.dnaftb.org/dnaftb**
An animated primer on the basics of DNA, genes and heredity.

DNA Interactive **www.dnai.org/index.htm**
DNA and genome-related teaching guides and lesson builders, personalized Web pages, My DNA, student activities, more.

Dolan Learning Center **www.dnalc.org**
Dolan's mission is to prepare students and families to thrive in the gene age, envisioning a day when all elementary students are exposed to principles of genetics and disease risk; when all high school students have the opportunity to do hands-on experiments with DNA; and when all families have access to genetic information they need to make informed health care choices. Includes an interactive DNA timeline.

Foundations of Classical Genetics **www.esp.org/foundations/genetics/classical**
Complete versions of classic genetics works written between 350 A.D. and 1932.

GeneTests **www.genetests.org/**
Information for health professionals about hundreds of genetic tests.

Genetic Counseling Program
www.hgen.pitt.edu/counseling/counseling/counsel_overview.htm
Clinical and educational information related to genetic counseling.

Genetic Science Learning Center **http://gslc.genetics.utah.edu**
From the Eccles Institute of Human Genetics at the University of Utah, a Web site created to help people understand how genetics affects their lives and society.

Genetic Testing: What It Means For Your Health and Your Family's Health
From the Trans-NIH Genetics Working Group for the Public

Genetics and Disease Prevention Information **www.cdc.gov/genomics/default.htm2**
Resources on genetics, including journals, reports and fact sheets. Also inlcudes online mulitmedia presentations ranging from basic genetics to latest research.

Genetics and Molecular Medicine (American Medical Association)
www.ama-assn.org/ama/pub/category/1799.html
Links to current articles and other resources

Genetics at About.Com **biology.about.com/cs/genetics/index.htm?terms=genetics**
Genetics Web resources featured at About.Com, a homework help site.

Genetics Education Center **www.kumc.edu/gec**
A comprehensive listing of genetics education resources, including networking sites, documentary films, lectures, booklets, activities, and programs. Compiled by the Genetics Education Center, University of Kansas Medical Center.

Genetics Education Partnership genetics-education-partnership.mbt.washington.edu
Teacher instruction guides, curricula, classroom activities and suggested outreach activities on genetics. Produced by the Genetics Education Partnership, a coalition of Washington state teachers and genetics professionals committed to genetics teaching.

Genetics: Educational Information **www.faseb.org/genetics/careers.htm**
Medical school courses in genetics, some with syllabi.

Genetics Home Reference **http://ghr.nlm.nih.gov**
Provides consumer information about genetic conditions and the genes or chromosomes responsible for those conditions.

Genetics Program for Nursing Faculty **www.gpnf.org**
Links to genetics resources of particular interest to nurses.

Genetics Origins **www.geneticorigins.org/geneticorigins**
Provides biochemical methods and computer tools to allow students to use their own DNA "fingerprints" as a starting point in the study of human evolution.

Genome Gateway **www.nature.com/genomics**
Comprehensive Web resource on genetic information. Hosted by Nature Publishing Company.

Genome News Network (The Center for the Advancement of Genomics)
www.genomenewsnetwork.org/index.php
Original articles and links

The Genomic Resource Centre **www.who.int/genomics/en**
From the World Health Organization, provides information and raises awareness on human genomics.

The Genomic Revolution
www.amnh.org/exhibitions/genomics/0_home/index.html
An online exhibit about genomics. Produced by the American Museum of Natural History, N.Y.

Howard Hughes Medical Institute **http://www.hhmi.org**
Excellent Virtual ELISA lab.

The Human Genome **www.ncbi.nlm.nih.gov/genome/guide/human/**
Comprehensive one-stop genomic information center. Hosted by the National Center for Biotechnology Information (NCBI) of the National Library of Medicine (NLM).

Human Genome Epidemiology Network (HuGENet)
http://www.cdc.gov/genomics/hugenet/default.htm
Hosted by the Centers for Disease Control (CDC), an international collaboration for sharing population-based human genome epidemiologic information.

Human Genome Project Education Resources
www.ornl.gov/hgmis/education/education.html
An extensive collection of publications, teaching aids, and additional internet resources. Hosted by the Human Genome Program of the U.S. Department of Energy.

infoGENETICS **www.infogenetics.org/**
Clinical practice tools.

IMMEX. Online problem solving. **http://www.immex.ucla.edu**
Several problems that are of particular interest to the Biotechnology classroom:

A. True Roots about children switched at birth. Use RFLP, blood typing, pedigrees to solve a young lady's parentage.
B. Mystery plasmid. Determine identity of vial of plasmid by comparing restriction maps and antibiotic resistances.
C. Ugly Gel asks students to trace their lab procedure steps to find an error in their DNA Fingerprint protocol (RFLP simulation) and to decide if the error renders their gel invalid for forensic use.

D. Frankenfoods asks students to determine what genes Dr. Frankenstein insterted into various plants. Then, they are asked to determine which gene is not expressing and where in the process of protein synthesis the error occurs (transcription, translation, expression).

These programs allow the teacher the ability to track and analyze student thinking.

Information for Genetics Professionals www.kumc.edu/gec/geneinfo.html
Educational, clinical, and research resources.

MendelWeb www.mendelweb.org/
Mendel's papers in English and German and related materials.

National Centre for Biotechnology Education http://www.ncbe.reading.ac.uk/
The University of Reading in Berkshire England runs this non-profit Web site, providing innovative educational resources. Read special features on GM foods and human genetics, download lab activities and protocols, or purchase equipment and materials at their online store.

National Coalition for Health Professional Education in Genetics www.nchpeg.org/
Core competencies in genetics and reviews of education programs.

National Library of Medicine: PubMed www.ncbi.nlm.nih.gov/PubMed
Basic search engine for biomedical research, including research and commentary regarding clinical research ethics and regulations.

National Human Genome Research Institute http://www.genome.gov/Education/
The National Human Genome Research Institute supports genetic and genomic research, investigation into the ethical, legal and social implications surrounding genetics research, and educational outreach activities.

The New Genetics: A Resource for Students and Teachers
www4.umdnj.edu/camlbweb/teachgen.html
Links to genetic education resources.

Online Mendelian Inheritance in Man (OMIM)
http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=OMIM
Information about human genes and disease.

Science News Presented by BIO (Biotechnology Industry Organization)
science.bio.org/genomics.news.html
Links to current articles

Scitable www.nature.com/scitable
A free science library and personal learning tool brought to you by Nature Publishing Group, the world's leading publisher of science. Scitable currently concentrates on genetics.

Understanding Gene Testing **www.accessexcellence.org/AE/AEPC/NIH/index.html**
An informative, illustrated tutorial on genes and genetic testing. Hosted by the National Cancer Institute.

What's a Genome?
http://www.genomenewsnetwork.org/resources/whats_a_genome/Chp1_1_1.shtml
An informative overview of genomics presented by the Genome News Network. Topics include: What's a Genome?, What's Genome Sequencing? and What's a Genome Map?

Your Genes Your Health **www.ygyh.org**
A multimedia guide to genetics disorders.

Your Genome **www.yourgenome.org**
Produced by the Wellcome Trust Sanger Institute, Your Genome provides an introduction to the main concepts of DNA, genes & genomes, focusing on basic questions such as "What is a genome?" and "What are genes?" There is also an introduction to the Human Genome Project and much more.