**Title:** The Technology of Biology

**Length of Course:** Full Year (2 semesters; 3 trimesters; 4 quarters)

**Subject Area – Discipline:** Laboratory Science - Biology ("d")

**CTE Sector:** Health Science and Medical Technology

**CTE Pathway:** Biotechnology

**Grade Level(s):** 9 -12

**Prerequisite(s):** Algebra 1 or IM 1

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**Course Overview:**

This one-year course for 9th and/or 10th graders serves to introduce the principles of biology through a biotechnological perspective. A general high school biology class focuses on the study of life ranging from the atoms that build up the macromolecules that serve as the foundation of life to how different ecosystems interact within a biosphere. Biotechnology aims to help improve our lives and the health of our planet by harnessing cellular and biomolecular processes. Students will use an integrated approach to study the principles that govern life while constantly referring to how these applications of biotechnology are attempting to improve life on earth. For example, modern biotechnology provides ground breaking products and technologies to combat diseases, reduce our environmental footprint, feed the hungry, use less and cleaner energy, and have safer, cleaner, and more efficient industrial manufacturing. This course challenges students to honestly evaluate the current problems faced in the 21st century and apply their knowledge of foundational biology to propose possible solutions using biotechnological techniques. Upon completion of the course, students will identify a medical or environmental problem, research possible products of biotech companies that are attempting to address that problem, prepare an advertisement campaign to educate the public of the identified problem, and justify why their product is the answer. Upon successful completion of the course, students will have a better understanding of current biological concepts and biotechnological applications.

## Unit 1: Molecules to Organisms: Structures to Process

This unit establishes the foundation for all subsequent units. Integrating medical examples and biotechnological applications, students develop an overview of the hierarchy of life from atoms to organisms. Students will acquire and demonstrate an understanding of the relationship between structure and function of biological systems. Student will also study laboratory methodologies such as the use of qualitative assays to detect the presence of macromolecules. Students will learn Current Good Laboratory

Practices for laboratory quality control (cGLP), proper laboratory documentation, the Global Harmonizing System for laboratory safety including sample storage (GHS), Standard Operating Procedures (SOPs) and use of laboratory instruments.

## Unit 1 - Assignments

### Assignment 1: Testing unknowns for the presence of biomolecules

This assignment allows students to learn about the different types of biomolecules and the means for detecting these molecules in solution. In preparation, students will learn Current Good Laboratory Practices (cGLP), proper laboratory documentation, and the Global Harmonizing System (GHS). Additionally, they learn how to use instruments found in a biotechnology laboratory such as micropipettes. Students follow Standard Operating Procedures (SOPs) to qualitatively detect the presence of nucleic acids, lipids, proteins, and carbohydrates with a colorimetric assay. Using the above techniques, students identify an unknown biomolecule in solution and document their experiment in a laboratory notebook. In addition to the laboratory experiment, students conduct a literature search about diseases that are related to these biomolecules. These diseases include: PKU and amino acids, sickle cell anemia and protein, diabetes and carbohydrates, coronary artery disease and the high lipid diet of Western society, and Huntington's disease and nucleic acids. Students share their findings through a multimedia presentation to their peers. This assignment will provide the foundational knowledge for the types of biomolecules important to life and foundational skills for detecting those molecules. Both the knowledge gained from the lab and the from the research will be further developed in the case study in assignment 2 which investigates a specific type of biomolecule.

### Assignment 2: Sickle Cell Anemia Case Study

After completing assignment 1, students will explore a type of defect in a biomolecule that affects humans. Using hemoglobin as an example of a protein biomolecule, students will explore the molecular biology central dogma of gene expression to protein structure. Given the DNA sequences from normal and sickle hemoglobin gene alleles, students will determine and compare the mRNA transcripts and the amino acid sequences. Students will research the effect of the point mutation leading to sickle cell anemia, research and compare the 3D crystalline structures of the normal and sickle hemoglobin proteins. Next, students will use microscopic examination of normal and sickle blood smears to observe the change in cell shape. Students will then make connections linking the changes in DNA, in protein and cellular structure to the detrimental physiological effects on the circulatory system. Students will write a paper synthesizing the information from gene to protein, from protein to cellular effect, and from cell to body system malfunction. Students will also include their research on various potential treatments for sickle cell anemia including gene expression of fetal hemoglobin. This case study demonstrates that scientific research about human diseases initially involves the understanding of the

fundamental concepts in molecular biology, cellular biology, and physiology, before drug design can occur.

### Assignment 3: Linking systems

After working through a model of system linkages using sickle cell anemia and the effect of disease on circulatory and respiratory systems, students will research another linkage between diseases such as asthma, cystic fibrosis, leukemia, celiac disease, or hepatitis, and the effect on the primary organ and system and the secondary effects on other organ systems. Afterwards, students will investigate whether treatments are available or are under development at biotechnology and/or pharmaceutical companies. Finally, the students will investigate the governmental regulatory process for drug development and production (FDA). Students will produce a multimedia presentation that explains the disease and malfunction of the linked organ systems, the interventions that are available or under investigation, and the process of drug discovery to consumer use.

### Assignment 4: Investigating mechanisms of maintaining homeostasis

Building from the biomolecule and organ system assignments, students will model the regulation of blood sugar with hormones in a negative feedback loop so that the body can maintain homeostasis. The model can be constructed from a simple lever device with sand representing hormones and candy representing blood sugar such as found in this lesson plan (http://www.lessonplansinc.com/lessonplans/feedback_mechanism_lab.pdf). After, students will research homeostasis disruption in diabetes and hypoglycemia and the pharmaceutical interventions that are available that attempt to restore homeostasis. Students will produce a formatted lesson plan, including all information gathered, to teach a family member about sugar regulation in the bloodstream.

## Unit 2: Heredity: Inheritance and Variation of Traits

Building on knowledge of biomolecules, students will learn how DNA, mRNA and proteins govern the cell. First, students must investigate the central dogma of biology and be able to explain how DNA is transcribed into mRNA and translated into protein. Using a case study of a genetic disease, students learn the principles of genetic inheritance and the probability of passing the disease on to their offspring. Students will then study how gene expression relates genotypic and phenotypic traits. Students will then study gene expression of beta-galactosidase in E. coli by utilizing spectrophotometry and graphing techniques to show beta-galactosidase activity. The students will explore a variety of biotechnological techniques (such PCR and restriction digest) and apply them to real world applications in the fields of medical diagnostics and forensics.

## Unit 2 - Assignments

### Assignment 1: Analysis of DNA Sequence to Organismal Phenotype

In this activity, students will decode provided DNA information to build a genetically unique dinosaur. Using a simulated genetic code table which converts codons to specific

traits, students will analyze DNA sequence to determine transcription, translation products, and possible phenotypes of this organism. Students will then simulate a cross between two dinosaurs, predict the potential offspring genotypes and phenotypes, and sculpt a 3D representation of one of the F1 progeny. Along with the sculpture, students will complete a written justification for the phenotype of each trait. This activity will reinforce the genetic information found in DNA that will be inherited from generation to generation and how they are expressed as physical traits (and proteins) in the organism, which is the foundation of biotechnology.

### Assignment 2: Research on Inheritable Traits Causing Genetic Disease and Genetic Testing of Inheritable Traits

Incorporating knowledge from the Design-o-Saur assignment, students will test themselves for the bitter taste trait to understand a phenotypic trait. The bitter taste test serves as an authentic example of how to use a phenotype to determine the genotypes in their ancestry. Students will then extend this knowledge and research an assigned genetically inherited trait such as sickle cell anemia, cystic fibrosis, hemochromatosis, etc. Utilizing the pedigree provided, students will complete a phylogenetic tree to identify the phenotype and the potential genotype(s) of each individual, which individuals in the family would carry the mutation and predict the probability that the offspring of the last generation would carry the mutation or have the disease. In order to explore genetic testing and medical diagnosis further, students will then explore a case study associated with Huntington's Disease. To do this, students will utilize virtual polymerase chain reaction (PCR) (HHMI Biointeractive) to analyze sample DNA for the presence of the normal or mutant allele of gene. Students will analyze PCR products utilizing agarose gel electrophoresis, a common technique in biotechnology labs. They will determine whether their patient carries the mutant allele of the gene and what is their probability of acquiring the disease. Now that students understand the scientific principles behind genetic testing in a laboratory, they will be asked to develop a list of instances where genetic testing would be advisable for individuals with incurable genetic diseases. Students will then engage in a debate addressing the genetic testing of currently incurable genetic diseases such as Huntington's Disease.

### Assignment 3: Spectrophotometric Analysis of Gene Expression

After mastering the basic concepts of molecular biology, the students are introduced to human diseases that are due to defects related to gene expression. For example, red-green color blindness and albinism results from problems of pigment production in the human body. In this activity, students will learn about regulation of specific genes, manipulate the amount of gene expression in bacteria, examine enzyme activity, and analyze the levels of protein production using a colorimetric method.
In order to introduce the concept of spectrophotometric assays, which are commonly used in a biotechnology lab, students will use cGLP standards with proper liquid handling and appropriate solution calculations utilizing metric and SI units to prepare five solutions of known concentrations, such as Copper (II) sulfate. They will utilize these solutions to generate a standard curve from spectrophotometric data. Using mathematical equations and their generated standard curve, they will determine the concentration of an unknown solution. Students will document their protocol, results, calculations and conclusions in their scientific notebook.

After mastering this common spectrophotometric analysis technique, students will apply that skill and use the same equipment to determine protein activity and the expression of the gene which codes from that protein. Students assay $\beta$ -galactosidase activity in E. coli. Bacteria containing the $\beta$ -galactosidase gene will be induced with varying levels of o-nitrophenyl- $\beta$ -D-galactopyraniside (ONPG). $\beta$ -galactosidase activity will be assayed utilizing the spectrophotometer to detect the presence of o-nitrophenyl. Students will construct a graph of the B-galactosidase activity level versus inducer concentration. Students will then use their graph in order to write the discussion section of a publication to share their findings.
Together these activities will help students connect the use of equipment in the biotechnology laboratory such as micropipettor and spectrophotometers to the determination of protein activity and the expression of the gene which codes for that protein.

### Assignment 4: Restriction Digest Analysis

Historically genetic testing of inherited disease involved restriction RFLPs and agarose gel electrophoresis. Students will learn about restriction enzymes, practice with a paper activity, practice with a computer simulation, and culminate with a hands on lab experiment. They will carry out a paper restriction digest in order to become familiar with how restriction enzymes cut DNA. Then students will carry out a restriction digest on the computer of lambda DNA with EcoR1 and HindIII in order to predict the number and size of fragments resulting from the digest. Students will then carry out the same experiment at the lab bench and will run an agarose gel electrophoresis in order to analyze and compare their digest fragments to the predicted results from above. Students will then write a brief lab report relating the predicted results to the actual results. This common molecular biology technique is used in forensic science to identify suspect/victim DNA left at crime scenes.

### Assignment 5: Crime Scene Analysis

Building upon Assignment 4, students will use their acquired knowledge of RFLPs to investigate the evidence in a simulated crime scene (such as the murder of Yale graduate student Annie Le). Students analyze the physical evidence using microscope analysis of hair and fibers, fingerprint examination, paper chromatography of ink samples, and DNA fingerprinting to implicate or exonerate potential suspects. Using the results from the evidence, students present their case in a mock trial as criminal lawyers in the prosecution of the suspect. The techniques that are practiced in this activity reinforce how biotechnology is utilized in solving crimes.

## Unit 3: Ecosystems: Interactions, Energy and Dynamics

In this unit, students will learn how matter, focusing on carbon, and energy move through organisms and ecosystems. Through laboratory work, students will learn how photosynthesis transforms light energy into stored chemical energy for growth. They will utilize previously learned biotechnological concepts such as cGLP notebook record keeping standards followed by learning the proper scientific format of journal article report writing. In a laboratory experiment, students will perform starch digestion experiments and quantify the amount of glucose formed. Following that, the students will make a creative story that follows the carbon atoms in a glucose molecule through the aerobic and anaerobic cycles of the human body. This allows the student to make a

connection between the food they eat and the energy provided by the food required for organism function. Following respiration, students will continue to follow the role of carbon dioxide in the ecosystem by creating an artistic representation of the carbon cycle, generating mathematical models and subsequently using them to predict future carbon dioxide levels and global temperatures, researching and discussing in peer group panels current proposals for decreasing the carbon footprint and proposing their own plan for the global climate change. Following this, the students will continue to investigate the ecosystem by researching, preparing pamphlets and newspaper articles of current agricultural biotechniques, genetically engineered food products, biotechnological companies imploring these techniques and any social or economic impact. The students will have the opportunity to formulate arguments for or against the use of a particular agriculture biotechnique and debate their position with logically formulated ideas. Finally, the students will use resources of mission logs from deepwater investigations to learn of the impact of individuals on a specific ecosystem. The ocean is used as a focus to continue the role of carbon dioxide in the ecosystem as the ocean decreases its ability to absorb excess carbon dioxide as global temperatures increase.

## Unit 3 - Assignments

### Assignment 1: Photosynthesis

Students will investigate the relationship of photosynthesis and respiration through the growth of plants and statistical analysis of biomass loss over time. In this lab, students will grow plants under two sets of conditions: sun exposure or darkness. After a set period of time, students will dry out the plants and measure the biomass. They can then link the energy requirement for photosynthesis to the production of biomass, or growth. Students will document their hypothesis, procedures, data and observations, discussion and conclusion in their laboratory notebook according to cGLP standards. Then, students will write a final formal laboratory report following all pertinent current journal writing standards including the abstract, introduction, procedures, data and observations, discussion and conclusion.

### Assignment 2: Digestion

In assignment 1, students learn that an increase in biomass is directly related to the energy requirement for photosynthesis. This increase in biomass results in an increase in plant starches. Students will build on this knowledge by performing a digestion lab of several food/plant sources containing starch with salivary amylase and analyze the amount of glucose generated during the digestion. This will emphasize the specificity of enzyme action in targeting specific types of starch as well as show the students what happens to food once they eat it. The students will comply with cGLP and record all procedures, data, observations and conclusions in their laboratory notebook. They will follow this up by writing a creative story following the carbons of their glucose molecule through the aerobic and anaerobic respiration cycles resulting in the loss of CO2. This provides foundational knowledge that prepares students for the next assignment.

### Assignment 3: Carbon Predictions

Following respiration, students will now continue following carbon in the form of carbon dioxide levels of the ecosystem as a whole and its global carbon cycle. In this assignment, students research the global carbon cycle and generate an artistic representation of the

global carbon cycle, illustrating all aspects of carbon dioxide emission and absorption. Students will then research data on the average global temperature and carbon dioxide levels and produce both a linear and exponential mathematical model which they will then use to predict the carbon dioxide levels at future points in time. In a one page report, students will answer the question: if humans continue releasing carbon dioxide into the atmosphere at current levels by burning coal, and natural gas, what future atmospheric carbon levels and average global temperatures can we expect? This work prepares students to make the recommendations for global climate change programs in the next assignment.

### Assignment 4: Global carbon dioxide levels

In assignment 3, students made predictions of future carbon dioxide levels. They will now take their predictions and build on it by investigating strategies for solving the climate problem. Groups of students will investigate the 15 Stabilization Wedges proposed by Pacala and Socolow in the categories of Efficiency and Conversion Strategies, Carbon Capture and Storage Strategies, Coal Replacement Strategies, Renewable Energy Strategies, and Biostorage Strategies for solving the climate problem. In discussion panels, students debate which 12 of the 15 stabilization wedges to implement and how to implement them. Students then use the Global Carbon Budget applet (http://carboncycle.aos.wisc.edu/carbon-budget-tool/) to determine if their use of the stabilization wedges would be successful in mitigating the feedback loop that is predicted to occur if carbon dioxide levels reach as high as 450 parts per million. They will synthesize this information and develop their own plan for solving the climate problem. The students will then give a multimedia presentation on their plan for solving the climate problem.

### Assignment 5: Ocean Ecosystem

Building on the knowledge gained in assignment 4 on global carbon dioxide levels, students will continue exploring and learning how the increasing atmospheric carbon dioxide levels have an effect on organisms and our ecosystem. Students investigate global warming and its effect on various ecosystems. Students will work collaboratively and present their findings in a poster presentation to educate their community about the effects of increasing $CO_2$ levels. The poster can include the theories of global warming and the different contributing factors and the effect of global warming on their ecosystem of choice. This assignment gives a visible, concrete cause and effect relationship between the environmental factors that affect global warming and the impact on the various ecosystems. For example, students can read mission logs from deep water ecosystem studies (Oceanexplorer.noaa.gov/explorations) to support arguments about how the distribution of deepwater organisms is affected by environmental factors.

### Assignment 6: Agricultural Biotechnology

As a result of the increasing population size and the increasing carbon footprint and requirement of carbon in the form of food, biotechnology companies are trying to maximize agricultural productivity. In this activity, students will investigate one of the biotechnological techniques implored by the agricultural industry: conventional plant breeding, tissue culture and micropropagation, molecular selective cross breeding, induced mutation assisted breeding or genetic engineering. Students will investigate a

biotechnology company (in their local area if possible) that uses their technique. They will then make a pamphlet explaining their biotechnological technique, relevant foundational biological concepts or processes involved, the company, environmental or social concerns, opposition, risk assessment, benefits/concerns. Through this process, students will learn from each other the different agricultural techniques and how they are used.

### Assignment 7: GMO Food Testing

In assignment 6, students learned different agricultural techniques employed by agricultural biotechnology companies which attempt to address the need for increased productivity and a decrease in the carbon footprint associated with supporting the increasing population. In this assignment, students will build on this knowledge with a laboratory experiment utilizing one of the agricultural techniques. They will focus on the agricultural technique of genetic engineering. Students will utilize polymerase chain reaction (PCR) to determine whether various different plants have been genetically modified. Students will learn about the labeling of food such as "organic", "certified organic" as determined by governmental regulatory agencies (FDA, EPA, USDA). They will hypothesize and then research which plants are most likely to be genetically modified. DNA will be extracted from common plant samples, such as those found in the grocery store. The genomic DNA will be used to perform a PCR reaction to detect a gene that has been inserted into the plant genome. As a control, the genomic DNA will be used in a separate PCR reaction to detect the presence of a common plant gene. Students will analyze their DNA gels utilizing gel electrophoresis. Utilizing their research on GMO plants and labeling, students will write a newspaper article reporting their test results of the foods tested at the local grocery store and whether those foods would require a GMO label.

### Assignment 8: Bioethics of Agricultural Biotechnology

As a result of the increasing agricultural biotechnological investigations, concerns about environmental and social impacts and risk/benefit analysis become more prevalent. Students will perform a close reading of the pros and cons of agricultural biotechnology Pro: "How Biotechnology is Helping Farmers & the Environment." (www. biotech-now.org) Cons: http://www.actionbioscience.org/biotechnology/altieri.html
Once the students have learned from each other the different agricultural biotechniques, companies and any environmental or social impacts from activity 5, they will formulate an argument (pro or con) for one of the five agricultural biotechniques. Students will then work in a group to create a commercial or other appropriate industry communications piece that is either for or against genetically modified crops. In this commercial students will need to discuss and defend their point of view in areas such as environmental or social concerns, risk to benefits assessment.

## Unit 4: Biological Evolution: Unity and Diversity

In this unit students will build upon their understanding of DNA and mutations leading to variable traits to develop an understanding of the major factors leading to evolutionary change: the potential for a species to increase in number, the heritable genetic variation due to mutations, competition for limited resources, and the resulting growth of population because they are better able to survive. By studying case studies, students will formulate an understanding of how natural selection and environmental changes can lead to the adaptation of populations and evolutionary change. Students will refine their

sterile laboratory techniques using cGLP to grow up a bacterial culture and analyze the evolutionary effect of selection pressure. Students will also learn the technique of designing an experiment and writing an appropriate Standard Operating Procedure using safety precautions of the Global Harmonising System.

## Unit 4 - Assignments

### Assignment 1: Case study of Lactose Intolerance

Students will use a variety of resources including the HHMI Biointeractive website, "Regulation of Lactase Gene", to examine and investigate scientific evidence regarding lactose tolerance. Lactose tolerance is an advantageous point mutation that enabled humans to digest lactose and use dairy as a consistent food resource. This advantageous mutation coincided with early human efforts to domesticate dairy producing livestock. Based on world population maps showing lactose tolerance and intolerance, and Lactase supplement sales data, students will draw conclusions about how this mutation impacted human population growth and migration. Using lactose tolerance as a comparative reference, students write a paper addressing one or more of the following: the natural selection of mutations, the ecological impacts that result from mutations, and the potential sociological impact of mutations on human life.

### Assignment 2: Point Mutation Leading to Streptomycin Resistance in E. coli (Lab)

In this activity, students perform a laboratory investigation that demonstrates a spontaneous point mutation for streptomycin resistance in a culture of E. coli bacteria. The students pour streptomycin containing gradient plates, plate the bacteria, and examine the plates for growth. Students then test their plate colonies for resistance by growing in a medium containing streptomycin. Students use their knowledge of point mutations and research scientific publications to examine examples of current antibiotic resistance. Using a multimedia presentation, they present their laboratory findings and its connection to their investigative research.

### Assignment 3: Design of Experiment (DOE) and Standard Operating Procedure (SOP)

Building on their knowledge from assignment 2, students (individually or in groups) use the bacteria strain from assignment 2 to design a new experiment that creates an opportunity for a spontaneous mutation in the bacteria. They use one or more of the following environmental stressors: pH, salinity levels, metals concentration. Students use the scientific method to develop and test their hypothesis about how environmental stressors impact and change the bacteria population. Using their hypothesis, students write a paper summarizing their experiment. Additionally, they write a SOP, standard operating procedure, that incorporates all appropriate safety precautions based upon the Global Harmonising System.

### Assignment 4: Using DNA to Explore Lizard Phylogeny

The students will watch "The Origin of Species: Lizards in an Evolutionary Tree" by Jonathan Losos in order to introduce the idea of convergent evolution. Students carry out a virtual laboratory experiment (HHMI) that investigates concepts in evolutionary biology, adaptation, convergent evolution, phylogenetic analysis, reproductive isolation, and speciation. Because evolution takes considerable time to study and analyze, a simulation allows students to duplicate in the classroom the kind of work that might take

years for a biotechnologist, and allows students to extend the learning and consider policy recommendations or interventions that emerge as a result of such research. During the virtual lab (see link in resources), students will collect data, carry out calculations and analyze the data in order to create a phylogenetic tree showing the evolution of a lizard population. Students will then propose hypothetical environmental stressors that might explain the data. In the end students, will propose possible local policies, based on additional research if necessary, that would prevent the environmental stress and its impact on the lizard population.

### Unit 5: Culminating Final Project

The culminating final project for this year long high school biology course is a research paper and an infomercial. Students will choose a current biological issue related to combating diseases, reducing environmental impact, increasing food production, producing sustainable energy , or streamlining industrial manufacturing. Students will research the underlying biological concepts of this issue, a biotech product which helps to address the problem, and the corporate profile of the biotechnology company that manufactures this product, including careers within the organization. The research paper should identify explain the current issue, make connections to biological concepts from this course, identify the specific biotech product and explain how that biotech product relates to or solves the issue. A description of the company that is producing the product and the careers available within that company should also be included. Additionally, students will create an infomercial that informs consumers about the science and benefits of this biotech product. This final project will reinforce the connection between scientific concepts, biotechnological applications and consumer products.

## Course Materials

### Resources:

### Unit 1: Molecules to Organisms: Structures to Process

- 15 min video on discovery of genetics of sickle cell disease through lens of human evolution: https://www.hhmi.org/biointeractive/making-fittest-natural-selection-humans
- Resources relating to sickle cell disease: http://bioquest.org/bioinformatics/module/tutorials/Sickle_Cell_Anemia/
- Protein structure of normal and sickle hemoglobin: http://publicationsonline.carnegiescience.edu/first_light_case/horn/lessons/sickle.html
- Virtual Cell: http://vcell.ndsu.nodak.edu/animations/flythrough/movie-flash.htm
- Hormone Homestasis Lab: http://www.lessonplansinc.com/lessonplans/feedback_mechanism_lab.pdf

### Unit 2: Heredity: Inheritance and Variation of Traits

- Design-o-saur activity: www.beyondbenign.org/K12education/biotech.../**Design**-O-**Saur**.doc
- B-Galactosidase Lab: http://rothlab.ucdavis.edu/protocols/beta-galactosidase-3.html
- PCR Virtual Lab: https://www.hhmi.org/biointeractive/bacterial-identification-virtual-lab

**Unit 3: Ecosystems: Interactions, Energy and Dynamics**

- Carbon-budget: http://carboncycle.aos.wisc.edu/carbon-budget-tool/
- Mission logs- Deep water ecosystems: Oceanexplorer.noaa.gov/explorations
- Pros vs. cons of Agriculutral biotech: http://www.actionbioscience.org/cocbiotechnology/lessons/altierilessons.pdf
- Pro: "How Biotechnology is Helping Farmers and the Environment." www.biotech-now.org
- Cons: http://www.actionbioscience.org/biotechnology/altieri.html
- leaf stomata research lab investigation: http://staff.concord.org/~btinker/gaiamatters/investigations/stomata.html

**Unit 4: Biological Evolution: Unity and Diversity**

- Preview Activity: http://www.hhmi.org/biointeractive/lactose-intolerance-fact-or-fiction
- Lactose Activity: http://www.hhmi.org/biointeractive/making-fittest-got-lactase-co-evolution-genes-and-culture
- Lactose Interactive: http://www.hhmi.org/biointeractive/regulation-lactase-gene
- The streptomycin resistance lab (see activity 4): http://bscs.org/sites/default/files/_legacy/pdf/Products_Bringing_RNA_into_View.pdf
- Lizard Evolution Virtual Lab: https://www.hhmi.org/biointeractive/lizard-evolution-virtual-lab
- Creating Phylogenetic Trees from DNA Sequences: http://www.hhmi.org/biointeractive/creating-phylogenetic-trees-dna-sequences
- Using DNA to Explore Lizard Phylogeny: http://www.hhmi.org/biointeractive/using-dna-explore-lizard-phylogeny