CASE

APB Expanded Lesson Review

The following is a compiled listing of the concepts, performance objectives, standards alignment, and essential questions by lesson.

Lesson 1.1 Foundations of Biotechnology

Concepts	Performance Objectives
Students will know and understand	*Students will learn concepts by doing*
1. Modern biotechnology has foundations in historical technologies, such as fermentation and selective breeding, while utilizing newer fields, such as molecular biology, bioengineering, and bioinformatics.	• Complete a series of activities to explore the applications of biotechnology. (Activity 1.1.1) • Write a definition of biotechnology. (Activity 1.1.1)
2. Organization and record keeping are important to success in biotechnology.	• Develop and maintain an *Agriscience Notebook* to store information for the course. (Activity 1.1.2) • Develop a Laboratory Notebook to record observations and protocols. (Activity 1.1.2)
3. Innovations in biotechnology have led to more efficient production of agricultural goods and may support sustainable agricultural practices in the future.	• Determine the date and significance of a biotechnological discovery. (Project 1.1.3) • Work collaboratively to develop a timeline of biotechnology discoveries. (Project 1.1.3)
4. Ethical questions surrounding applications of biotechnology, which generate discussions and varying opinions that drive policy and regulation, are based on personal beliefs.	• Explore their personal beliefs and knowledge to gain perspective on practices in biotechnology. (Activity 1.1.4)

National AFNR Common Career Technical Core Standards Alignment

Career Ready Practices
8. Utilize critical thinking to make sense of problems and persevere in solving them.
• CRP.08.01: Apply reason and logic to evaluate workplace and community situations from multiple perspectives.
Agriculture, Food, and Natural Resources Career Cluster
1. Analyze how issues, trends, technologies and public policies impact systems in the Agriculture, Food & Natural Resources Career Cluster.
• AG 1.2: Describe current issues impacting AFNR activities.
• AG 1.6: Recognize the historical, social, cultural and potential applications of biotechnology on AFNR activities.
Agribusiness Systems Career Pathway (AG-BIZ)
2. Use record keeping to accomplish AFNR business objectives, manage budgets and comply with laws and regulations.
• AG-BIZ 2.2: Prepare and maintain all files as needed for effective record keeping practices.

Biotechnology Systems Career Pathway
BS.01: Assess factors that have influenced the evolution of biotechnology in agriculture (e.g., historical events, societal trends, ethical and legal implications, etc.).
• BS.01.01: Investigate and explain the relationship between past, current and emerging applications of biotechnology in agriculture (e.g., major innovators, historical developments, potential applications of biotechnology, etc.).

Next Generation Science Standards Alignment

Disciplinary Core Ideas	
Science and Engineering Practices	
Obtaining, Evaluating, and Communicating Information	Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

Understandings about the Nature of Science	
Scientific Investigations Use a Variety of Methods	• New technologies advance scientific knowledge.
Science is a Human Endeavor	• Scientific knowledge is a result of human endeavor, imagination, and creativity. • Individuals and teams from many nations and cultures have contributed to science and to advances in engineering. • Scientists' backgrounds, theoretical commitments, and fields of endeavor influence the nature of their findings. • Technological advances have influenced the progress of science and science has influenced advances in technology. • Science and engineering are influenced by society and society is influenced by science and engineering.
Science Addresses Questions About the Natural and Material World.	• Not all questions can be answered by science. • Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. • Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. • Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues.

Common Core State Standards for English Language Arts

CCSS: English Language Arts Standards » Science & Technical Subjects » Grade 11-12	
Key Ideas and Details	• **RST.11-12.2 –** Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
Craft and Structure	• **RST.11-12.4 –** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.
Range of Reading and Level of Text Complexity	• **RST.11-12.10 –** By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently.

CCSS: English Language Arts Standards » Writing » Grade 11-12	
Production and Distribution of Writing	• **WHST.11-12.4 –** Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
Research to Build and Present Knowledge	• **WHST.11-12.7 –** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. • **WHST.11-12.8 –** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.

Range of Writing	• **WHST.11-12.10 –** Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Essential Questions

1. How does biotechnology impact agriculture?
2. What disciplines contribute to biotechnology?
3. Why are accurate laboratory notebooks important?
4. Why is organization valuable to research and experimentation?
5. How are laboratory notebooks organized?
6. How have past discoveries and research influenced biotechnology today?
7. How is biotechnology used to solve problems?
8. How do personal beliefs influence understanding of biotechnology?
9. Why is biotechnology a controversial subject?
10. How will biotechnology influence the future of agriculture?
11. What misunderstandings about biotechnology influence public opinion?

Lesson 1.2 Standard Operating Procedures

Concepts	**Performance Objectives**
Students will know and understand	*Students will learn concepts by doing*
1. Working in a biotechnology laboratory requires diligence in following safety procedures and rules.	• Review the Lab Safety Manual and determine safe practices for the biotechnology laboratory. (Activity 1.2.1)
2. Knowledge of the location of safety equipment is essential when working in the laboratory.	• Diagram and describe where emergency equipment and safety hazards in the biotechnology laboratory are located. (Activity 1.2.1) • Explain appropriate uses of safety and emergency equipment. (Activity 1.2.1)
3. Safety Data Sheets (SDS) contain important information related to the proper use and cleanup of biological and chemical materials.	• Use SDS forms to determine the proper use and clean up of compounds used in the course. (Activity 1.2.2)
4. Proper and accurate measurement is important for laboratory investigation.	• Mix diluted solutions based on the percentage of a substance desired. (Activity 1.2.3) • Prepare solutions based on the desired molar concentration. (Activity 1.2.4) • Use pipets to transfer accurate volumes of solutions. (Activity 1.2.5) • Transfer microliters of solutions using a micropipet. (Activity 1.2.5)
5. Good Laboratory Procedures (GLPs) ensure the quality and integrity of laboratory data used to support registration of a product.	• Prepare and pour nutrient agar plates using sterile procedures. (Activity 1.2.6)

National AFNR Common Career Technical Core Standards Alignment

Career Ready Practices
1. Act as a responsible and contributing citizen and employee.
• CRP.01.01: Model personal responsibility in the workplace and community.

Agriculture, Food, and Natural Resources Career Cluster
3. Examine and summarize importance of health, safety, and environmental management systems in AFNR organizations.
• AG.3.5: Enact procedures that demonstrate the importance of safety, health, and environmental responsibilities in the workplace.
• AG.3.7: Demonstrate application of personal and group health and safety practices.

Biotechnology Systems Career Pathway Content Standards
BS.02: Demonstrate proficiency by safely applying appropriate laboratory skills to complete tasks in a biotechnology research and development environment (e.g., standard operating procedures, record keeping, aseptic technique, equipment maintenance, etc.).
• BS.02.03: Apply standard operating procedures for the safe handling of biological and chemical materials in a laboratory.
• BS.02.04: Safely manage and dispose of biological materials, chemicals and wastes according to standard operating procedures.

Next Generation Science Standards Alignment

Disciplinary Core Ideas	
Science and Engineering Practices	
Planning and Carrying Out Investigations	Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • Select appropriate tools to collect, record, analyze, and evaluate data.

Understandings about the Nature of Science	
Scientific Investigations Use a Variety of Methods	• Scientific investigations use a variety of methods, tools, and techniques to revise and produce new knowledge.

Common Core State Standards for High School Mathematics

Modeling standards are indicated by the star symbol (*) throughout other conceptual categories.

CCSS: Conceptual Category – Algebra	
Seeing Structure in Expressions	• *Write expressions in equivalent forms to solve problems.
Arithmetic with Polynomials and Rational Expressions	• Perform arithmetic operations on polynomials.
Reasoning with Equations and Inequalities	• Solve systems of equations.

CCSS: Conceptual Category – Functions	
Interpreting Functions	• Understand the concept of a function and use function notation.

Common Core State Standards for English Language Arts

CCSS: English Language Arts Standards » Science & Technical Subjects » Grade 11-12	
Key Ideas and Details	• **RST.11-12.1 –** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
Range of Reading and Level of Text Complexity	• **RST.11-12.10 –** By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently.

CCSS: English Language Arts Standards » Writing » Grade 11-12	
Range of Writing	• **WHST.11-12.10 –** Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Essential Questions

1. What are proper safety procedures when working in a laboratory?
2. Where is the emergency equipment located in the laboratory?
3. What guidelines am I expected to follow when working in the laboratory?
4. What information is included in an SDS?
5. What is a percent solution?
6. What is the formula used to calculate dilutions of the concentration of solutions?
7. What is the difference between mole and molarity?
8. What is a molar solution?
9. How do percent and molar solutions compare?
10. How do the various types of pipets differ?
11. How are culture plates prepared?
12. Why are culture plates used in biotechnology?

Lesson 1.3 Basics of Cells and DNA

Concepts	Performance Objectives
Students will know and understand	*Students will learn concepts by doing*
1. Culturing research specimen in the laboratory requires the use of sterile techniques to limit contamination.	• Prepare culture plates using proper sterile and streaking techniques. (Activity 1.3.1)
2. Prokaryotic and eukaryotic cells, which are used for biotechnological applications, can be cultured and observed easily in the laboratory.	• Observe differences in growth patterns of prokaryote and eukaryote model organisms. (Activity 1.3.1)
3. Understanding DNA structure is essential for bioengineering processes.	• Develop a model of a DNA strand as a class and using simulation materials. (Activity 1.3.2)
4. DNA is studied in order to understand how living things work.	• Research DNA replication and develop a visual representation of the replication process. (Project 1.3.3) • Determine the location of a specific gene sequence in a DNA segment. (Activity 1.3.4)

National AFNR Common Career Technical Core Standards Alignment

Biotechnology Systems Career Pathway Content Standards
BS.02: Demonstrate proficiency by safely applying appropriate laboratory skills to complete tasks in a biotechnology research and development environment (e.g., standard operating procedures, record keeping, aseptic technique, equipment maintenance, etc.).
• BS.02.05: Examine and perform scientific procedures using microbes, DNA, RNA and proteins in a laboratory.

Next Generation Science Standards Alignment

Disciplinary Core Ideas	
Life Science	
LS1: From Molecules to Organisms: Structures and Processes	
LS1.A: Structure and Function	• All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells.
LS3: Heredity: Inheritance and Variation of Traits	
LS3.A: Inheritance of Traits	• Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function.

Science and Engineering Practices	
Developing and Using Models	Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. • Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.

Crosscutting Concepts	
Patterns	Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.
	• Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
Cause and Effect: Mechanism and Prediction	Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.
	• Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. • Systems can be designed to cause a desired effect.
Scale, Proportion, and Quantity	In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.
	• The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. • Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.
Systems and System Models	A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.
	• Systems can be designed to do specific tasks. • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. • Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.
Structure and Function	The way an object is shaped or structured determines many of its properties and functions.
	• Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. • The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

Common Core State Standards for English Language Arts

CCSS: English Language Arts Standards » Science & Technical Subjects » Grade 11-12	
Integration of Knowledge and Ideas	• **RST.11-12.7 –** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
Range of Reading and Level of Text Complexity	• **.RST.11-12.10 –** By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently.

CCSS: English Language Arts Standards » Writing » Grade 11-12	
Production and Distribution of Writing	• **WHST.11-12.4 –** Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
Research to Build and Present Knowledge	• **WHST.11-12.7 –** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
Range of Writing	• **WHST.11-12.10 –** Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Essential Questions

1. How are prokaryotic and eukaryotic cells used in biotechnology?
2. Why are model organisms valuable in biotechnology?
3. How is contamination avoided when streaking plates?
4. How can *E. coli* be beneficial in research?
5. Why does the sequence of nucleotides in DNA matter?
6. Why is knowledge of DNA essential for biotechnology?
7. How are DNA molecules organized?
8. How is DNA polymerase used in replication?
9. How is the process of DNA replication used in biotechnology?
10. How do biotechnologists direct DNA processes?
11. Do all DNA base pairs code for genes?
12. How can a specific gene be identified in the genetic sequence of an organism?

Lesson 2.1 Diving into DNA

Concepts	Performance Objectives
Students will know and understand	*Students will learn concepts by doing*
1. DNA is extracted from cellular matter to be studied.	• Write an experiment to extract DNA from kiwi fruit. (Project 2.1.1) • Extract DNA from kiwi fruit using procedures developed. (Project 2.1.1) • Mix solutions and pour gel trays to prepare agarose gels. (Activity 2.1.2) • Conduct gel electrophoresis to observe the migration of dyes and extracted DNA. (Activity 2.1.3)

2. Restriction enzymes are used to cut DNA in order to compare organisms, isolate and transfer genes, and genetically modify organisms.	• Demonstrate the action of restriction enzymes using paper DNA strands. (Activity 2.1.4)
3. DNA profiles are created using fragments produced through Restriction Fragment Length Polymorphism.	• Digest a DNA sample using restriction enzymes and conduct gel electrophoresis to analyze the results. (Activity 2.1.5) • Solve a problem determining the culprit of a crime using restriction enzymes and gel electrophoresis. (Problem 2.1.6)

National AFNR Common Career Technical Core Standards Alignment

Biotechnology Systems Career Pathway Content Standards
BS.02: Demonstrate proficiency by safely applying appropriate laboratory skills to complete tasks in a biotechnology research and development environment (e.g., standard operating procedures, record keeping, aseptic technique, equipment maintenance, etc.).
• BS.02.03: Apply standard operating procedures for the safe handling of biological and chemical materials in a laboratory.
• BS.02.05: Examine and perform scientific procedures using microbes, DNA, RNA and proteins in a laboratory.

Next Generation Science Standards Alignment

Disciplinary Core Ideas	
Life Science	
LS1: From Molecules to Organisms: Structures and Processes	
LS1.A: Structure and Function	• Systems of specialized cells within organisms help them perform the essential functions of life. • All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells.
LS3: Heredity: Inheritance and Variation of Traits	
LS3.A: Inheritance of Traits	• Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function.
LS4: Biological Evolution: Unity and Diversity	
LS4.A: Evidence of Common Ancestry and Diversity	• Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.

Science and Engineering Practices	
Asking Questions and Defining Problems	Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Ask questions that arise from careful observation of phenomena, or unexpected results ▪ to clarify and/or seek additional information. ▪ that arise from examining models or a theory, to clarify and/or seek additional information and relationships. ▪ to determine relationships, including quantitative relationships, between independent and dependent variables. ▪ to clarify and refine a model, an explanation, or an engineering problem. • Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.
Planning and Carrying Out Investigations	Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing

	solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. • Select appropriate tools to collect, record, analyze, and evaluate data. • Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. • Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables.
Constructing Explanations and Designing Solutions	Constructing explanations and designing solutions in 9–12 builds on K– 8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Crosscutting Concepts	
Patterns	Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.
	• Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. • Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments.
Scale, Proportion, and Quantity	In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.
	• Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.
Systems and System Models	A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.
	• Systems can be designed to do specific tasks. • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Understandings about the Nature of Science	
Scientific Investigations Use a Variety of Methods	• Science investigations use diverse methods and do not always use the same set of procedures to obtain data. • Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings. • Scientific investigations use a variety of methods, tools, and techniques to revise and produce new knowledge.
Science is a Way of Knowing	• Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise, and extend this knowledge.

Common Core State Standards for High School Mathematics

Modeling standards are indicated by the star symbol (*) throughout other conceptual categories.

CCSS: Conceptual Category – Number and Quantity	
Quantities	• *Reason quantitatively and use units to solve problems.

CCSS: Conceptual Category – Algebra	
Seeing Structure in Expressions	• *Interpret the structure of expressions. • *Write expressions in equivalent forms to solve problems.
Arithmetic with Polynomials and Rational Expressions	• Perform arithmetic operations on polynomials.
Creating Equations	• *Create equations that describe numbers or relationships.
Reasoning with Equations and Inequalities	• Understand solving equations as a process of reasoning and explain the reasoning. • Solve equations and inequalities in one variable.

Common Core State Standards for English Language Arts

CCSS: English Language Arts Standards » Science & Technical Subjects » Grade 11-12	
Key Ideas and Details	• **RST.11-12.2 –** Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
Range of Reading and Level of Text Complexity	• **RST.11-12.10 –** By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently.

CCSS: English Language Arts Standards » Writing » Grade 11-12	
Production and Distribution of Writing	• **WHST.11-12.4 –** Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. • **WHST.11-12.5 –** Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.
Research to Build and Present Knowledge	• **WHST.11-12.7 –** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
Range of Writing	• **WHST.11-12.10 –** Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Essential Questions

1. How is DNA extracted from a cell?
2. Why does DNA need to be extracted from a cell?
3. How is agarose different from agar?
4. How do I prepare a 1x solution from a 50x solution?
5. Why is a comb necessary in the gel tray?
6. Why is a Tris/acetic acid/EDTA buffer used in electrophoresis instead of water?
7. How does gel electrophoresis work?
8. What color dye moves the furthest during electrophoresis?
9. How can you predict where a restriction enzyme will cut DNA?
10. How many times can a restriction enzyme cut a strand of DNA?
11. What is a lambda bacteria phage?
12. How is Restriction Fragment Length Polymorphism used in biotechnology?
13. What are applications of gel electrophoresis?

Lesson 2.2 Genetic Transformers

Concepts	Performance Objectives
Students will know and understand 1. Transformation is used to synthetically produce proteins for increased animal and plant production.	*Students will learn concepts by doing* • Prepare agar plates and LB broth for transformation. (Activity 2.2.1) • Transform bacterial cells to exhibit ampicillin resistance and bioluminescence. (Activity 2.2.2)

2. Plasmids are used to insert the genes for desired traits into bacterial cells.	• Use the pGLO plasmid to transform bacterial cells to exhibit desired traits. (Activity 2.2.2) • Research how the Ti plasmid is used to transform a bacteria of interest for agricultural biotechnology applications. (Project 2.2.4)
3. Proteins of interest can be purified from bacterial cultures for further study.	• Culture transformed cells and purify a protein of interest from the bacteria. (Activity 2.2.3)
4. Conducting background research is important to identify what is already known about the research objective.	• Research *Agrobacterium tumefaciens* to determine applications in the agricultural field. (Project 2.2.4) • Write a scientific research paper using valid resources and parenthetical citations. (Project 2.2.4)

National AFNR Common Career Technical Core Standards Alignment

Career Ready Practices
4. Communicate clearly, effectively and with reason.
• CRP.04.02: Produce clear, reasoned and coherent written and visual communication in formal and informal settings.
7. Employ valid and reliable research strategies.
• CRP.07.02: Evaluate the validity of sources and data used when considering the adoption of new technologies, practices and ideas in the workplace and community.
Agriculture, Food, and Natural Resources Career Cluster
1. Analyze how issues, trends, technologies and public policies impact systems in the Agriculture, Food & Natural Resources Career Cluster.
• AG.1.6: Recognize the historical, social, cultural and potential applications of biotechnology on AFNR activities.
• AG.1.7: Demonstrate the application of biotechnology to AFNR activities.
Biotechnology Systems Career Pathway Content Standards
BS.02: Demonstrate proficiency by safely applying appropriate laboratory skills to complete tasks in a biotechnology research and development environment (e.g., standard operating procedures, record keeping, aseptic technique, equipment maintenance, etc.).
• BS.02.02: Implement standard operating procedures for the proper maintenance, use and sterilization of equipment in a laboratory.
• BS.02.03: Apply standard operating procedures for the safe handling of biological and chemical materials in a laboratory.
• BS.02.04: Safely manage and dispose of biological materials, chemicals and wastes according to standard operating procedures.
• BS.02.05: Examine and perform scientific procedures using microbes, DNA, RNA and proteins in a laboratory.
BS.03: Demonstrate the application of biotechnology to solve problems in AFNR systems (e.g., bioengineering, food processing, waste management, horticulture, forestry, livestock, crops, etc.).
• BS.03.01: Apply biotechnology principles, techniques and processes to create transgenic species through genetic engineering.

Next Generation Science Standards Alignment

Disciplinary Core Ideas	
Engineering, Technology, and the Application of Science	
ETS1: Engineering Design	
ETS1.A: Defining and Delimiting	• Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

Engineering Problems	
ETS1.B: Developing Possible Solutions	• When evaluating solutions, it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts.

Science and Engineering Practices	
Constructing Explanations and Designing Solutions	Constructing explanations and designing solutions in 9–12 builds on K– 8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. • Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.
Obtaining, Evaluating, and Communicating Information	Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. • Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. • Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. • Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. • Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

Crosscutting Concepts	
Patterns	Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.
	• Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system.
Cause and Effect: Mechanism and Prediction	Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.
	• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. • Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.

Understandings about the Nature of Science	
Scientific Knowledge is Based on Empirical Evidence	• Science knowledge is based on empirical evidence. • Science disciplines share common rules of evidence used to evaluate explanations about natural systems. • Science includes the process of coordinating patterns of evidence with current theory. • Science arguments are strengthened by multiple lines of evidence supporting a single explanation.
Scientific Knowledge is Open to Revision in Light of New Evidence	• Scientific explanations can be probabilistic. • Most scientific knowledge is quite durable but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence.
Science is a Way of Knowing	• Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise, and extend this knowledge. • Science distinguishes itself from other ways of knowing through use of empirical standards, logical arguments, and skeptical review.

Science is a Human Endeavor	• Scientific knowledge is a result of human endeavor, imagination, and creativity. • Technological advances have influenced the progress of science and science has influenced advances in technology. • Science and engineering are influenced by society and society is influenced by science and engineering.
Science Addresses Questions About the Natural and Material World.	• Not all questions can be answered by science. • Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. • Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. • Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues.

Common Core State Standards for High School Mathematics

Modeling standards are indicated by the star symbol (*) throughout other conceptual categories.

CCSS: Conceptual Category – Number and Quantity	
Quantities	• *Reason quantitatively and use units to solve problems.
The Complex Number System	• Perform arithmetic operations with complex numbers.

CCSS: Conceptual Category – Algebra	
Seeing Structure in Expressions	• *Interpret the structure of expressions. • *Write expressions in equivalent forms to solve problems.
Creating Equations	• *Create equations that describe numbers or relationships.
Reasoning with Equations and Inequalities	• Solve equations and inequalities in one variable.

Common Core State Standards for English Language Arts

CCSS: English Language Arts Standards » Science & Technical Subjects » Grade 11-12	
Key Ideas and Details	• **RST.11-12.2 –** Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
Craft and Structure	• **RST.11-12.4 –** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.
Range of Reading and Level of Text Complexity	• **RST.11-12.10 –** By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently.

CCSS: English Language Arts Standards » Writing » Grade 11-12	
Text Types and Purposes	**WHST.11-12.2 –** Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. • **WHST.11-12.2.A –** Introduce a topic and organize complex ideas, concepts, and information so that each new element builds on that which precedes it to create a unified whole; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension. • **WHST.11-12.2.B –** Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic. • **WHST.11-12.2.C –** Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts. • **WHST.11-12.2.D –** Use precise language, domain-specific vocabulary and techniques such as metaphor, simile, and analogy to manage the complexity of the topic; convey a knowledgeable stance in a style that responds to the discipline and context as well as to the expertise of likely readers. • **WHST.11-12.2.E –** Provide a concluding statement or section that follows from and supports the information or explanation provided (e.g., articulating implications or the significance of the topic).
Production and Distribution of Writing	• **WHST.11-12.4 –** Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. • **WHST.11-12.5 –** Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.

	• **WHST.11-12.6 –** Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.
Research to Build and Present Knowledge	• **WHST.11-12.7 –** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. • **WHST.11-12.8 –** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. • **WHST.11-12.9 –** Draw evidence from informational texts to support analysis, reflection, and research.
Range of Writing	• **WHST.11-12.10 –** Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Essential Questions

1. How is LB agar media modified to be selective?
2. How are plasmids used in genetic modification?
3. What is the difference between a plasmid and other types of DNA?
4. Why are plasmids inserted into bacterial cells?
5. How is ampicillin resistance observed?
6. How can I determine if cells have been transformed with the pGLO plasmid?
7. How can a specific protein be removed from bacterial cells?
8. How is *A. tumefaciens* important to agriculture?
9. How do I conduct valid background research?
10. How do researchers choose and use resources for information?
11. How do I avoid plagiarizing?

Lesson 3.1 Protein Processes

Concepts	**Performance Objectives**
Students will know and understand	*Students will learn concepts by doing*
1. Transcription and translation are processes that produce proteins of which all living things are made.	• Research the processes of transcription and translation and complete a simulation of amino acid production. (Activity 3.1.1)
2. Colorimetric assays can be used to identify and determine the amount of protein in a biological sample extract.	• Perform an experiment using a spectrophotometer to assess the protein content of milk and other high protein drinks. (Activity 3.1.2) • Compare the results of Bradford assays to Biuret assays. (Activity 3.1.3)
3. The presence of specific proteins in a biological sample can indicate the presence of disease, exposure to disease, or identify genetically modified products.	• Complete an enzyme-linked immunosorbent assay to determine the presence of protein. (Activity 3.1.4)

	• Write an outline of their research paper on *Agrobacterium tumefaciens*. (Project 2.2.4 continuation)

National AFNR Common Career Technical Core Standards Alignment

Agriculture, Food, and Natural Resources Career Cluster
1. Analyze how issues, trends, technologies and public policies impact systems in the Agriculture, Food & Natural Resources Career Cluster.
• AG.1.7: Demonstrate the application of biotechnology to AFNR activities.
3. Examine and summarize importance of health, safety, and environmental management systems in AFNR organizations.
• AG.3.7: Demonstrate application of personal and group health and safety practices.
Biotechnology Systems Career Pathway Content Standards
BS.02: Demonstrate proficiency by safely applying appropriate laboratory skills to complete tasks in a biotechnology research and development environment (e.g., standard operating procedures, record keeping, aseptic technique, equipment maintenance, etc.).
• BS.02.05: Examine and perform scientific procedures using microbes, DNA, RNA and proteins in a laboratory.
BS.03: Demonstrate the application of biotechnology to solve problems in AFNR systems (e.g., bioengineering, food processing, waste management, horticulture, forestry, livestock, crops, etc.).
• BS.03.02: Apply biotechnology principles, techniques and processes to enhance the production of food through the use of microorganisms and enzymes.
• BS.03.04: Apply biotechnology principles, techniques and processes to enhance plant and animal care and production (e.g., selective breeding, pharmaceuticals, biodiversity, etc.).

Next Generation Science Standards Alignment

Disciplinary Core Ideas	
Life Science	
LS1: From Molecules to Organisms: Structures and Processes	
LS1.A: Structure and Function	• Systems of specialized cells within organisms help them perform the essential functions of life.
LS1.C: Organization for Matter and Energy Flow in Organisms	• As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.
LS3: Heredity: Inheritance and Variation of Traits	
LS3.A: Inheritance of Traits	• Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function.

Science and Engineering Practices	
Developing and Using Models	Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
Analyzing and Interpreting Data	Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

	• Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. • Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. • Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. • Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. • Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success.
Using Mathematics and Computational Thinking	Mathematical and computational thinking in 9-12 builds on K-8 and experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. • Apply techniques of algebra and functions to represent and solve scientific and engineering problems. • Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.).
Obtaining, Evaluating, and Communicating Information	Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. • Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. • Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. • Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. • Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

Crosscutting Concepts	
Patterns	Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.
	• Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
Scale, Proportion, and Quantity	In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.
	• The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. • Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. • Patterns observable at one scale may not be observable or exist at other scales.

Understandings about the Nature of Science	
Scientific Investigations Use a Variety of Methods	• Science investigations use diverse methods and do not always use the same set of procedures to obtain data. • New technologies advance scientific knowledge. • The discourse practices of science are organized around disciplinary domains that share exemplars for making decisions regarding the values, instruments, methods, models, and evidence to adopt and use. • Scientific investigations use a variety of methods, tools, and techniques to revise and produce new knowledge.

Common Core State Standards for High School Mathematics

Modeling standards are indicated by the star symbol (*) throughout other conceptual categories.

CCSS: Conceptual Category – Statistics and Probability	
Interpreting Categorical and Quantitative Data	• *Summarize, represent, and interpret data on a single count or measurement variable. • *Interpret linear models.
Making Inferences and Justifying Conclusions	• *Make inferences and justify conclusions from sample surveys, experiments, and observational studies.

Common Core State Standards for English Language Arts

CCSS: English Language Arts Standards » Science & Technical Subjects » Grade 11-12	
Key Ideas and Details	• **RST.11-12.1 –** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. • **RST.11-12.2 –** Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
Craft and Structure	• **RST.11-12.4 –** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.
Range of Reading and Level of Text Complexity	• **RST.11-12.10 –** By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently.

CCSS: English Language Arts Standards » Writing » Grade 11-12	
Text Types and Purposes	**WHST.11-12.2 –** Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. • **WHST.11-12.2.A –** Introduce a topic and organize complex ideas, concepts, and information so that each new element builds on that which precedes it to create a unified whole; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension. • **WHST.11-12.2.B –** Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic. • **WHST.11-12.2.C –** Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts. • **WHST.11-12.2.D –** Use precise language, domain-specific vocabulary and techniques such as metaphor, simile, and analogy to manage the complexity of the topic; convey a knowledgeable stance in a style that responds to the discipline and context as well as to the expertise of likely readers. • **WHST.11-12.2.E –** Provide a concluding statement or section that follows from and supports the information or explanation provided (e.g., articulating implications or the significance of the topic).
Production and Distribution of Writing	• **WHST.11-12.4 –** Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. • **WHST.11-12.5 –** Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. • **WHST.11-12.6 –** Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.
Research to Build and Present Knowledge	• **WHST.11-12.7 –** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. • **WHST.11-12.8 –** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. • **WHST.11-12.9 –** Draw evidence from informational texts to support analysis, reflection, and research.

Range of Writing	• **WHST.11-12.10 –** Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Essential Questions

1. How is protein synthesis used in biotechnology?
2. How are amino acids related to DNA?
3. How do the processes of transcription and translation produce proteins?
4. How can I determine the concentration of protein in a solution?
5. How does light absorbance indicate protein concentration?
6. How are specific proteins identified in substances?
7. Why are proteins significant in agricultural biotechnology?
8. How do protein-detection assays differ?

Lesson 4.1 Genetically Modified Organisms

Concepts	Performance Objectives
Students will know and understand	*Students will learn concepts by doing*
1. Ethical and moral questions arise from the science of genetically modifying organisms.	• Reflect upon the term genetically modified and develop personal perceptions and beliefs pertaining to the term. (Activity 4.1.1) • Research published perceptions of genetically modified organisms of different groups and organizations and discuss in class. (Activity 4.1.1) • Conduct a public perception survey of genetically modified foods. (Project 4.1.4)
2. Genetic testing, such as polymerase chain reactions and lateral flow tests, is used to make production based decisions and identify genetically modified organisms.	• Perform a lateral flow test to determine the presence of Round-Up Ready® genes in corn. (Activity 4.1.2) • Conduct a polymerase chain reaction to determine the presence of genetic modifications in a common food item. (Activity 4.1.3)
3. Organisms are genetically modified to improve agricultural products by inserting genes into cells.	• Complete the annotated bibliography, the rough draft, and a peer review of the *A. tumefaciens* research paper. (Project 2.2.4 continuation)

National AFNR Common Career Technical Core Standards Alignment

Career Ready Practices
4. Communicate clearly, effectively and with reason.
• CRP.04.02: Produce clear, reasoned and coherent written and visual communication in formal and informal settings.
5. Consider the environmental, social and economic impacts of decisions.
• CRP.05.01: Assess, identify and synthesize the information and resources needed to make decisions that positively impact the workplace and community.
• CRP.05.02: Make, defend and evaluate decisions at work and in the community using information about the potential environmental, social and economic impacts.

7. Employ valid and reliable research strategies.
• CRP.07.01: Select and implement reliable research processes and methods to generate data for decision-making in the workplace and community.
• CRP.07.02: Evaluate the validity of sources and data used when considering the adoption of new technologies, practices and ideas in the workplace and community.
8. Utilize critical thinking to make sense of problems and persevere in solving them.
• CRP.08.01: Apply reason and logic to evaluate workplace and community situations from multiple perspectives.
Agriculture, Food, and Natural Resources Career Cluster
1. Analyze how issues, trends, technologies and public policies impact systems in the Agriculture, Food & Natural Resources Career Cluster.
• AG.01.02: Describe current issues impacting AFNR activities.
• AG.01.04: Consider public input in decision-making for AFNR activities.
• AG.01.05: Explain the impact of sustainability on AFNR activities and practices.
• AG.01.06: Recognize the historical, social, cultural and potential applications of biotechnology on AFNR activities.
• AG.01.07: Demonstrate the application of biotechnology to AFNR activities.
Biotechnology Systems Career Pathway Content Standards
BS.01: Assess factors that have influenced the evolution of biotechnology in agriculture (e.g., historical events, societal trends, ethical and legal implications, etc.).
• BS.01.01: Investigate and explain the relationship between past, current and emerging applications of biotechnology in agriculture (e.g., major innovators, historical developments, potential applications of biotechnology, etc.).
• BS.01.02: Evaluate the scope and implications of regulatory agencies on applications of biotechnology in agriculture and protection of public interests (e.g., health, safety, environmental issues, etc.).
• BS.01.03: Analyze the relationship and implications of bioethics, laws and public perceptions on applications of biotechnology in agriculture (e.g., ethical, legal, social, cultural issues).
BS.02: Demonstrate proficiency by safely applying appropriate laboratory skills to complete tasks in a biotechnology research and development environment (e.g., standard operating procedures, record keeping, aseptic technique, equipment maintenance, etc.).
• BS.02.05: Examine and perform scientific procedures using microbes, DNA, RNA and proteins in a laboratory.
BS.03: Demonstrate the application of biotechnology to solve problems in AFNR systems (e.g., bioengineering, food processing, waste management, horticulture, forestry, livestock, crops, etc.).
• BS.03.06: Apply biotechnology principles, techniques and processes to improve waste management (e.g., genetically modified organisms, bioremediation, etc.).
Plant Systems (AG-PL)
3. Propagate, culture, and harvest plants and plant products based on current industry standards.
• AG-PL.03.09: Demonstrate the application of biotechnology to plant production.

Next Generation Science Standards Alignment

Disciplinary Core Ideas	
Engineering, Technology, and the Application of Science	
ETS1: Engineering Design	
ETS1.A: Defining and Delimiting Engineering Problems	• Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. • Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.
ETS1.B: Developing Possible Solutions	• When evaluating solutions, it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts.

Science and Engineering Practices	
Asking Questions and Defining Problems	Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Ask questions that arise from careful observation of phenomena, or unexpected results ▪ to clarify and/or seek additional information. ▪ that arise from examining models or a theory, to clarify and/or seek additional information and relationships. ▪ to clarify and refine a model, an explanation, or an engineering problem.
Analyzing and Interpreting Data	Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. • Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. • Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. • Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.
Constructing Explanations and Designing Solutions	Constructing explanations and designing solutions in 9–12 builds on K– 8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. • Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. • Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.
Engaging in Argument from Evidence	Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. • Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. • Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions.
Obtaining, Evaluating, and Communicating Information	Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. • Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. • Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. • Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. • Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

Crosscutting Concepts	
Structure and Function	The way an object is shaped or structured determines many of its properties and functions.
	• Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. • The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.
Stability and Change	For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.
	• Much of science deals with constructing explanations of how things change and how they remain stable. • Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. •

Understandings about the Nature of Science	
Scientific Investigations Use a Variety of Methods	• Science investigations use diverse methods and do not always use the same set of procedures to obtain data. • New technologies advance scientific knowledge. • Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings..
Scientific Knowledge is Based on Empirical Evidence	• Science knowledge is based on empirical evidence. • Science arguments are strengthened by multiple lines of evidence supporting a single explanation.
Scientific Knowledge is Open to Revision in Light of New Evidence	• Scientific explanations can be probabilistic. • Most scientific knowledge is quite durable but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. • Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation.
Science is a Human Endeavor	• Scientific knowledge is a result of human endeavor, imagination, and creativity. • Individuals and teams from many nations and cultures have contributed to science and to advances in engineering. • Technological advances have influenced the progress of science and science has influenced advances in technology. • Science and engineering are influenced by society and society is influenced by science and engineering.
Science Addresses Questions About the Natural and Material World.	• Not all questions can be answered by science. • Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. • Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. • Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues.

Common Core State Standards for English Language Arts

CCSS: English Language Arts Standards » Science & Technical Subjects » Grade 11-12	
Key Ideas and Details	• **RST.11-12.1 –** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
Craft and Structure	• **RST.11-12.4 –** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.
Range of Reading and Level of Text Complexity	• **RST.11-12.10 –** By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently.

CCSS: English Language Arts Standards » Writing » Grade 11-12	
Text Types and Purposes	**WHST.11-12.2 –** Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. • **WHST.11-12.2.A –** Introduce a topic and organize complex ideas, concepts, and information so that each new element builds on that which precedes it to create a unified whole; include formatting

	(e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension. • **WHST.11-12.2.B –** Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic. • **WHST.11-12.2.C –** Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts. • **WHST.11-12.2.D –** Use precise language, domain-specific vocabulary and techniques such as metaphor, simile, and analogy to manage the complexity of the topic; convey a knowledgeable stance in a style that responds to the discipline and context as well as to the expertise of likely readers. • **WHST.11-12.2.E –** Provide a concluding statement or section that follows from and supports the information or explanation provided (e.g., articulating implications or the significance of the topic).
Production and Distribution of Writing	• **WHST.11-12.4 –** Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. • **WHST.11-12.5 –** Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. • **WHST.11-12.6 –** Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.
Research to Build and Present Knowledge	• **WHST.11-12.7 –** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. • **WHST.11-12.8 –** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. • **WHST.11-12.9 –** Draw evidence from informational texts to support analysis, reflection, and research.
Range of Writing	• **WHST.11-12.10 –** Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Essential Questions

1. How do genetic modifications occur?
2. Why should I be concerned about GM as an agricultural biotechnician?
3. What are the advantages and disadvantages of GM crops?
4. How do personal beliefs influence acceptance of GM technologies?
5. What do lateral flow strips detect?
6. How are lateral flow strips similar to ELISA plate tests?
7. Why would I need to test for presence of GM in a field or production facility?
8. How does PCR detect the presence of genetic modifications?
9. How do lateral flow strips compare to PCR and electrophoresis in detecting genetic modifications?
10. How does consumer perception affect acceptance of GM foods?

Lesson 4.2 Performance Enhanced Plants

Concepts	Performance Objectives
Students will know and understand	*Students will learn concepts by doing*
1. Plants are genetically modified to improve agricultural products by inserting genes into cells.	• Research and compare methods of inserting genes into plants and discuss the advantages and disadvantages of each. (Activity 4.2.1)
2. The totipotency of plants allows a minute portion of tissue to be cultured into a complete plant.	• Propagate ferns using tissue culture. (Activity 4.2.2)
3. A sterile environment, including media, work area, equipment, and lab technician is required to produce viable plants by micropropagation.	• Sanitize, sterilize, and maintain an aseptic environment to promote success during tissue culture. (Activity 4.2.2)
4. Deoxyribonucleic acid (DNA) can be cut, replicated, and inserted into the genome of an organism for the improvement of agricultural production.	• Complete a simulation of the process for developing transgenic plants. (Activity 4.2.3) • Develop and write a protocol to insert a gene of interest in plants. (Problem 4.2.4)

National AFNR Common Career Technical Core Standards Alignment

Career Ready Practices
2. Apply appropriate academic and technical skills.
• CRP.02.02: Use strategic thinking to connect and apply technical concepts to solve problems in the workplace and community.
6. Demonstrate creativity and innovation.
• CRP.06.02: Assess a variety of workplace and community situations to identify ways to add value and improve the efficiency of processes and procedures.
• CRP.06.03: Create and execute a plan of action to act upon new ideas and introduce innovations to workplace and community organizations.
7. Employ valid and reliable research strategies.
• CRP.07.01: Select and implement reliable research processes and methods to generate data for decision-making in the workplace and community.
Agriculture, Food, and Natural Resources Career Cluster
1. Analyze how issues, trends, technologies and public policies impact systems in the Agriculture, Food & Natural Resources Career Cluster.
• AG 1.6: Recognize the historical, social, cultural and potential applications of biotechnology on AFNR activities.
• AG.1.7: Demonstrate the application of biotechnology to AFNR activities.
Biotechnology Systems Career Pathway Content Standards
BS.01: Assess factors that have influenced the evolution of biotechnology in agriculture (e.g., historical events, societal trends, ethical and legal implications, etc.).
• BS.01.01: Investigate and explain the relationship between past, current and emerging applications of biotechnology in agriculture (e.g., major innovators, historical developments, potential applications of biotechnology, etc.).
BS.02: Demonstrate proficiency by safely applying appropriate laboratory skills to complete tasks in a biotechnology research and development environment (e.g., standard operating procedures, record keeping, aseptic technique, equipment maintenance, etc.).
• BS.02.01: Read, document, evaluate and secure accurate laboratory records of experimental protocols, observations and results.

• BS.02.02: Implement standard operating procedures for the proper maintenance, use and sterilization of equipment in a laboratory.
• BS.02.04: Safely manage and dispose of biological materials, chemicals and wastes according to standard operating procedures.
BS.03: Demonstrate the application of biotechnology to solve problems in AFNR systems (e.g., bioengineering, food processing, waste management, horticulture, forestry, livestock, crops, etc.).
• BS.03.01: Apply biotechnology principles, techniques and processes to create transgenic species through genetic engineering.
• BS.03.04: Apply biotechnology principles, techniques and processes to enhance plant and animal care and production (e.g., selective breeding, pharmaceuticals, biodiversity, etc.).
• BS.03.06: Apply biotechnology principles, techniques and processes to improve waste management (e.g., genetically modified organisms, bioremediation, etc.).
Plant Systems (AG-PL)
3. Propagate, culture, and harvest plants and plant products based on current industry standards.
• AG-PL 3.7: Demonstrate plant propagation techniques.
• AG-PL 3.9: Demonstrate the application of biotechnology to plant production.

Next Generation Science Standards Alignment

Disciplinary Core Ideas	
Life Science	
LS1: From Molecules to Organisms: Structures and Processes	
LS1.A: Structure and Function	• Systems of specialized cells within organisms help them perform the essential functions of life. • Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.
LS4: Biological Evolution: Unity and Diversity	
LS4.C: Adaptation	• Adaptation also means that the distribution of traits in a population can change when conditions change. • Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. •
Engineering, Technology, and the Application of Science	
ETS1: Engineering Design	
ETS1.A: Defining and Delimiting Engineering Problems	• Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. • Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.
ETS1.B: Developing Possible Solutions	• When evaluating solutions, it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts.

Science and Engineering Practices	
Asking Questions and Defining Problems	Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations.
Developing and Using Models	Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

Planning and Carrying Out Investigations	Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts.
Obtaining, Evaluating, and Communicating Information	Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. • Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. • Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

Crosscutting Concepts	
Cause and Effect: Mechanism and Prediction	Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.
	• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. • Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. • Systems can be designed to cause a desired effect. • Changes in systems may have various causes that may not have equal effects.
Systems and System Models	A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.
	• Systems can be designed to do specific tasks. • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. • Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Understandings about the Nature of Science	
Scientific Investigations Use a Variety of Methods	• Science investigations use diverse methods and do not always use the same set of procedures to obtain data. • New technologies advance scientific knowledge. • Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings. • The discourse practices of science are organized around disciplinary domains that share exemplars for making decisions regarding the values, instruments, methods, models, and evidence to adopt and use. • Scientific investigations use a variety of methods, tools, and techniques to revise and produce new knowledge.

Common Core State Standards for English Language Arts

CCSS: English Language Arts Standards » Science & Technical Subjects » Grade 11-12	
Craft and Structure	• **RST.11-12.4 –** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.
Range of Reading and Level of Text Complexity	• **RST.11-12.10 –** By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently.

CCSS: English Language Arts Standards » Writing » Grade 11-12	
Range of Writing	• **WHST.11-12.10 –** Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Essential Questions

1. How are modified genes inserted into plants?
2. How do the different methods of inserting genes into plants compare?
3. How can I clone a plant?
4. What requirements do plants have in order to be propagated by tissue culture?
5. What is the difference between propagation by tissue culture and propagation by cuttings?
6. What is an explant?
7. What are the steps required to complete tissue culture?
8. Why is sterile technique important when cloning plants via tissue culture?
9. What are the steps in engineering a plant?
10. What is the difference between a plasmid and a vector?
11. How are transgenic plants tested to determine the success of engineering?
12. How is a new gene taken from development to production?

Lesson 4.3 Animal Applications

Concepts	**Performance Objectives**
Students will know and understand	*Students will learn concepts by doing*
1. The immune response of mammals can be used to detect proteins of interest.	• Perform enzyme-linked immunosorbent assays to detect the immunological response of animals. (Activity 4.3.1)
2. Animal reproductive technologies are used by producers in order to achieve management goals.	• Research and present their findings on reproductive technologies used in animal agriculture. (Project 4.3.2)
3. Markers are used to identify the successful insertion of genes.	• Perform PCR and electrophoresis to use marker assisted selection to determine ideal genotypes for specific situations. (Activity 4.3.3)
4. Genetic testing and disease diagnosis are used to make production based decisions.	• Complete a WebQuest to study the diagnostic tools available for detection of diseases and genetic abnormalities. (Project 4.3.4)

National AFNR Common Career Technical Core Standards Alignment

Agriculture, Food, and Natural Resources Career Cluster
1. Analyze how issues, trends, technologies and public policies impact systems in the Agriculture, Food & Natural Resources Career Cluster.
• AG 1.6: Recognize the historical, social, cultural and potential applications of biotechnology on AFNR activities.
• AG.1.7: Demonstrate the application of biotechnology to AFNR activities.
Animal Systems Career Pathway (AG-ANI)
1. Analyze historic and current trends impacting the animal systems industry.
• AG-ANI 1.4: Recognize the historical, social, cultural and potential applications of biotechnology in the animal systems industry.

4. Apply principles of animal reproduction given desired outcomes for performance, development and/or economic production.
• AG-ANI 4.2: Apply scientific techniques in breeding of animals.
• AG-ANI 4.4: Demonstrate the application of biotechnology to AFNR activities.
7. Apply principles of effective animal health care.
• AG-ANI 7.1: Implement a prevention and treatment program for animal diseases, parasites and other disorders for a given animal.
Biotechnology Systems Career Pathway Content Standards
BS.01: Assess factors that have influenced the evolution of biotechnology in agriculture (e.g., historical events, societal trends, ethical and legal implications, etc.).
• BS.01.01: Investigate and explain the relationship between past, current and emerging applications of biotechnology in agriculture (e.g., major innovators, historical developments, potential applications of biotechnology, etc.).
BS.02: Demonstrate proficiency by safely applying appropriate laboratory skills to complete tasks in a biotechnology research and development environment (e.g., standard operating procedures, record keeping, aseptic technique, equipment maintenance, etc.).
• BS.02.05: Examine and perform scientific procedures using microbes, DNA, RNA and proteins in a laboratory.
BS.03: Demonstrate the application of biotechnology to solve problems in AFNR systems (e.g., bioengineering, food processing, waste management, horticulture, forestry, livestock, crops, etc.).
• BS.03.04: Apply biotechnology principles, techniques and processes to enhance plant and animal care and production (e.g., selective breeding, pharmaceuticals, biodiversity, etc.).

Next Generation Science Standards Alignment

Disciplinary Core Ideas	
Life Science	
LS1: From Molecules to Organisms: Structures and Processes	
LS1.B: Growth and Development of Organisms	• In multicellular organisms, individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism.
Engineering, Technology, and the Application of Science	
ETS1: Engineering Design	
ETS1.A: Defining and Delimiting Engineering Problems	• Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. • Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.
ETS1.B: Developing Possible Solutions	• When evaluating solutions, it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts.

Science and Engineering Practices	
Asking Questions and Defining Problems	Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Ask questions that arise from careful observation of phenomena, or unexpected results ▪ to clarify and/or seek additional information. ▪ that arise from examining models or a theory, to clarify and/or seek additional information and relationships. ▪ to determine relationships, including quantitative relationships, between independent and dependent variables. ▪ to clarify and refine a model, an explanation, or an engineering problem.

	• Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.
Analyzing and Interpreting Data	Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
Obtaining, Evaluating, and Communicating Information	Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. • Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. • Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. • Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. • Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

Crosscutting Concepts	
Cause and Effect: Mechanism and Prediction	Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.
	• Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. • Systems can be designed to cause a desired effect.

Understandings about the Nature of Science	
Science is a Human Endeavor	• Individuals and teams from many nations and cultures have contributed to science and to advances in engineering. • Technological advances have influenced the progress of science and science has influenced advances in technology. • Science and engineering are influenced by society and society is influenced by science and engineering.
Science Addresses Questions About the Natural and Material World.	• Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. • Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge.

Common Core State Standards for English Language Arts

CCSS: English Language Arts Standards » Science & Technical Subjects » Grade 11-12	
Range of Reading and Level of Text Complexity	• **RST.11-12.10 –** By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently.

CCSS: English Language Arts Standards » Writing » Grade 11-12	
Production and Distribution of Writing	• **WHST.11-12.4 –** Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. • **WHST.11-12.6 –** Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.
Research to Build and Present Knowledge	• **WHST.11-12.7 –** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. • **WHST.11-12.8 –** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms

	of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.
Range of Writing	• **WHST.11-12.10 –** Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Essential Questions

1. What applications of biotechnology exist in animal agriculture?
2. How can diseases be diagnosed using enzyme-linked immunosorbent assays?
3. How have advances in animal reproductive technologies changed the genetic selection of animals?
4. What species of animals are artificial insemination and embryo transfer commonly used for?
5. How can the sex of offspring be manipulated prior to fertilization?
6. How is marker assisted selection used in animal agriculture?
7. How can specific genes linked to desired traits be selected for?
8. What types of diagnostic tests are available for livestock and small animals?

Lesson 4.4 Everyday Biotechnology

Concepts	**Performance Objectives**
Students will know and understand	*Students will learn concepts by doing*
1. Biotechnological practices, such as bioremediation, use naturally occurring processes to provide industrial applications.	• Design and conduct an experiment determining the effectiveness of oil-eating microbes in various environmental conditions. (Project 4.4.1)
2. Biofuels are a source of renewable energy derived from organisms.	• Research a type of biofuel. (Project 4.4.2)
3. Fermentation and esterification are processes in which agricultural products are converted into biofuels.	• Determine a method of producing the fuel in a laboratory. (Project 4.4.2)
4. The precautionary principle serves as a guiding statement for determining the ethical considerations of biotechnology and other scientific endeavors.	• Review a case study and interpret the application of the precautionary principle by interest groups. (Project 4.4.3)

National AFNR Common Career Technical Core Standards Alignment

Career Ready Practices
2. Apply appropriate academic and technical skills.
• CRP.02.01: Use strategic thinking to connect and apply academic learning, knowledge and skills to solve problems in the workplace and community.
• CRP.02.02: Use strategic thinking to connect and apply technical concepts to solve problems in the workplace and community.
4. Communicate clearly, effectively and with reason.
• CRP.04.02: Produce clear, reasoned and coherent written and visual communication in formal and informal settings.
5. Consider the environmental, social and economic impacts of decisions.
• CRP.05.02: Make, defend and evaluate decisions at work and in the community using information about the potential environmental, social and economic impacts.

7. Employ valid and reliable research strategies.

- CRP.07.01: Select and implement reliable research processes and methods to generate data for decision-making in the workplace and community.
- CRP.07.02: Evaluate the validity of sources and data used when considering the adoption of new technologies, practices and ideas in the workplace and community.

Agriculture, Food, and Natural Resources Career Cluster

1. Analyze how issues, trends, technologies and public policies impact systems in the Agriculture, Food & Natural Resources Career Cluster.

- AG 1.3: Identify, organize alternatives, and evaluate public policy issues related to AFNR.
- AG.1.7: Demonstrate the application of biotechnology to AFNR activities.

4. Demonstrate stewardship of natural resources in AFNR activities.

- AG.4.1: Demonstrate evidence of interest and concern for natural resource stewardship.

Biotechnology Systems Career Pathway Content Standards

BS.01: Assess factors that have influenced the evolution of biotechnology in agriculture (e.g., historical events, societal trends, ethical and legal implications, etc.).

- BS.01.01: Investigate and explain the relationship between past, current and emerging applications of biotechnology in agriculture (e.g., major innovators, historical developments, potential applications of biotechnology, etc.).
- BS.01.02: Evaluate the scope and implications of regulatory agencies on applications of biotechnology in agriculture and protection of public interests (e.g., health, safety, environmental issues, etc.).
- BS.01.03: Analyze the relationship and implications of bioethics, laws and public perceptions on applications of biotechnology in agriculture (e.g., ethical, legal, social, cultural issues).

BS.03: Demonstrate the application of biotechnology to solve problems in AFNR systems (e.g., bioengineering, food processing, waste management, horticulture, forestry, livestock, crops, etc.).

- BS.03.03: Apply biotechnology principles, techniques and processes to protect the environment and maximize use of natural resources (e.g., biomass, bioprospecting, industrial biotechnology, etc.).
- BS.03.05: Apply biotechnology principles, techniques and processes to produce biofuels (e.g., fermentation, transesterification, methanogenesis, etc.).
- BS.03.06: Apply biotechnology principles, techniques and processes to improve waste management (e.g., genetically modified organisms, bioremediation, etc.).

Next Generation Science Standards Alignment

Disciplinary Core Ideas	
Life Science	
LS1: From Molecules to Organisms: Structures and Processes	
LS1.C: Organization for Matter and Energy Flow in Organisms	• As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.
LS4: Biological Evolution: Unity and Diversity	
LS4.D: Biodiversity and Humans	• Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.
Earth and Space Science	
ESS3: Earth and Human Activity	
ESS3.A: Natural Resources	• All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.

ESS3.C: Human Impacts on Earth Systems	• Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.
Engineering, Technology, and the Application of Science	
ETS1: Engineering Design	
ETS1.A: Defining and Delimiting Engineering Problems	• Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. • Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.
ETS1.B: Developing Possible Solutions	• When evaluating solutions, it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts.

Science and Engineering Practices	
Asking Questions and Defining Problems	Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Ask questions that arise from careful observation of phenomena, or unexpected results ▪ to clarify and/or seek additional information. • Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. • Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations.
Planning and Carrying Out Investigations	Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts.
Constructing Explanations and Designing Solutions	Constructing explanations and designing solutions in 9–12 builds on K– 8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
Obtaining, Evaluating, and Communicating Information	Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. • Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. • Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

Crosscutting Concepts	
Cause and Effect: Mechanism and Prediction	Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.
	• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. • Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. • Systems can be designed to cause a desired effect. • Changes in systems may have various causes that may not have equal effects.

Understandings about the Nature of Science	
Science is a Human Endeavor	• Scientific knowledge is a result of human endeavor, imagination, and creativity. • Technological advances have influenced the progress of science and science has influenced advances in technology. • Science and engineering are influenced by society and society is influenced by science and engineering.
Science Addresses Questions About the Natural and Material World.	• Not all questions can be answered by science. • Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. • Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues.

Common Core State Standards for English Language Arts

CCSS: English Language Arts Standards » Science & Technical Subjects » Grade 11-12	
Key Ideas and Details	• **RST.11-12.1 –** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. • **RST.11-12.3 –** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
Integration of Knowledge and Ideas	• **RST.11-12.7 –** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. • **RST.11-12.8 –** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
Range of Reading and Level of Text Complexity	• **RST.11-12.10 –** By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently.

CCSS: English Language Arts Standards » Writing » Grade 11-12	
Research to Build and Present Knowledge	• **WHST.11-12.8 –** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. • **WHST.11-12.9 –** Draw evidence from informational texts to support analysis, reflection, and research.
Range of Writing	• **WHST.11-12.10 –** Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Essential Questions

1. How is biotechnology used in non-food producing applications?
2. What is bioremediation?
3. What advantages does bioremediation offer over traditional environmental cleanup methods?
4. How can biotechnology contribute to solving the world energy crisis?
5. What is the primary product of biofuels?
6. How is ethanol, or other biofuel products, separated from biomass?
7. How does the production of biofuels influence the amount of energy resources available?
8. How do scientists determine whether it is appropriate to conduct a scientific experiment?
9. What does a precautionary approach to science include?
10. Why are guidelines and oversight of scientific research important?

Lesson 5.1 Independent Researchers

Concepts	Performance Objectives
Students will know and understand	*Students will learn concepts by doing*
1. Research is driven by questions and backed by literature reviews, experimentation, and communication of results.	• Brainstorm ideas for research projects and define a problem to solve in order to frame research. (Activity 5.1.1)
2. Conducting background research is important to identify what is known about the research question.	• Collect and summarize similar research conclusions. (Activity 5.1.1)
3. Experiments are designed in such a way that the control is apparent and the researcher can conduct multiple trials.	• Write a research proposal outlining the background and need for their research as well as a plan for conducting the research. (Project 5.1.2) • Conduct a self-designed research project and collect data for results and analysis. (Project 5.1.2)
4. Results of research experiments include interpretation of data in the form of posters, papers, or oral presentations.	• Write a research paper summarizing the findings of their research. (Project 5.1.2) • Prepare a research poster to present to the class and at local science fairs. (Project 5.1.2)

National AFNR Common Career Technical Core Standards Alignment

Career Ready Practices
1. Act as a responsible and contributing citizen and employee.
• CRP.01.01: Model personal responsibility in the workplace and community.
2. Apply appropriate academic and technical skills.
• CRP.02.01: Use strategic thinking to connect and apply academic learning, knowledge and skills to solve problems in the workplace and community.
• CRP.02.02: Use strategic thinking to connect and apply technical concepts to solve problems in the workplace and community.
4. Communicate clearly, effectively and with reason.
• CRP.04.01: Speak using strategies that ensure clarity, logic, purpose and professionalism in formal and informal settings.
• CRP.04.02: Produce clear, reasoned and coherent written and visual communication in formal and informal settings.
7. Employ valid and reliable research strategies.
• CRP.07.01: Select and implement reliable research processes and methods to generate data for decision-making in the workplace and community.
• CRP.07.02: Evaluate the validity of sources and data used when considering the adoption of new technologies, practices and ideas in the workplace and community.
8. Utilize critical thinking to make sense of problems and persevere in solving them.
• CRP.08.02: Investigate, prioritize and select solutions to solve problems in the workplace and community.
9. Model integrity, ethical leadership and effective management.
• CRP.09.02: Implement personal management skills to function effectively and efficiently in the workplace (e.g., time management, planning, prioritizing, etc.).
12. Work productively in teams while using cultural/global competence.
• CRP.12.01: Contribute to team-oriented projects and build consensus to accomplish results using cultural global competence in the workplace and community.
• CRP.12.02: Create and implement strategies to engage team members to work toward team and organizational goals in a variety of workplace and community situations (e.g., meetings, presentations, etc.).

Agriculture, Food, and Natural Resources Career Cluster
1. Analyze how issues, trends, technologies and public policies impact systems in the Agriculture, Food & Natural Resources Career Cluster.
• AG 1.6: Recognize the historical, social, cultural and potential applications of biotechnology on AFNR activities.
• AG.1.7: Demonstrate the application of biotechnology to AFNR activities.
Biotechnology Systems Career Pathway Content Standards
BS.01: Assess factors that have influenced the evolution of biotechnology in agriculture (e.g., historical events, societal trends, ethical and legal implications, etc.).
• BS.01.01: Investigate and explain the relationship between past, current and emerging applications of biotechnology in agriculture (e.g., major innovators, historical developments, potential applications of biotechnology, etc.).
BS.02: Demonstrate proficiency by safely applying appropriate laboratory skills to complete tasks in a biotechnology research and development environment (e.g., standard operating procedures, record keeping, aseptic technique, equipment maintenance, etc.).
• BS.02.01: Read, document, evaluate and secure accurate laboratory records of experimental protocols, observations and results.
• BS.02.02: Implement standard operating procedures for the proper maintenance, use and sterilization of equipment in a laboratory.
• BS.02.03: Apply standard operating procedures for the safe handling of biological and chemical materials in a laboratory.
• BS.02.04: Safely manage and dispose of biological materials, chemicals and wastes according to standard operating procedures.

Next Generation Science Standards Alignment

Disciplinary Core Ideas	
Engineering, Technology, and the Application of Science	
ETS1: Engineering Design	
ETS1.A: Defining and Delimiting Engineering Problems	• Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.
ETS1.B: Developing Possible Solutions	• When evaluating solutions, it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts.

Science and Engineering Practices	
Asking Questions and Defining Problems	Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Ask questions that arise from careful observation of phenomena, or unexpected results ▪ to clarify and/or seek additional information. ▪ that arise from examining models or a theory, to clarify and/or seek additional information and relationships. ▪ to determine relationships, including quantitative relationships, between independent and dependent variables. ▪ to clarify and refine a model, an explanation, or an engineering problem. • Evaluate a question to determine if it is testable and relevant. • Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. • Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. • Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations.
	Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

Planning and Carrying Out Investigations	• Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. • Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts. • Select appropriate tools to collect, record, analyze, and evaluate data. • Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. • Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables.
Analyzing and Interpreting Data	Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. • Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. • Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success.
Constructing Explanations and Designing Solutions	Constructing explanations and designing solutions in 9–12 builds on K– 8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. • Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. • Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. • Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
Engaging in Argument from Evidence	Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. • Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. • Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions. • Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. • Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence.
Obtaining, Evaluating, and Communicating Information	Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. • Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

Understandings about the Nature of Science	
Scientific Investigations Use a Variety of Methods	• Science investigations use diverse methods and do not always use the same set of procedures to obtain data. • Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings. • Scientific investigations use a variety of methods, tools, and techniques to revise and produce new knowledge.
Science is a Human Endeavor	• Scientific knowledge is a result of human endeavor, imagination, and creativity. • Individuals and teams from many nations and cultures have contributed to science and to advances in engineering. • Scientists' backgrounds, theoretical commitments, and fields of endeavor influence the nature of their findings.
Science Addresses Questions About the Natural and Material World.	• Not all questions can be answered by science. • Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge

Common Core State Standards for High School Mathematics

Modeling standards are indicated by the star symbol (*) throughout other conceptual categories.

CCSS: Conceptual Category – Statistics and Probability	
Interpreting Categorical and Quantitative Data	• *Summarize, represent, and interpret data on a single count or measurement variable.
Making Inferences and Justifying Conclusions	• *Understand and evaluate random processes underlying statistical experiments. • *Make inferences and justify conclusions from sample surveys, experiments, and observational studies.

Common Core State Standards for English Language Arts

CCSS: English Language Arts Standards » Science & Technical Subjects » Grade 11-12	
Key Ideas and Details	• **RST.11-12.1 –** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
Craft and Structure	• **RST.11-12.4 –** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.
Integration of Knowledge and Ideas	• **RST.11-12.7 –** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. • **RST.11-12.8 –** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
Range of Reading and Level of Text Complexity	• **RST.11-12.10 –** By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently.

CCSS: English Language Arts Standards » Writing » Grade 11-12	
Text Types and Purposes	**WHST.11-12.2 –** Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. • **WHST.11-12.2.A –** Introduce a topic and organize complex ideas, concepts, and information so that each new element builds on that which precedes it to create a unified whole; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension. • **WHST.11-12.2.B –** Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic. • **WHST.11-12.2.C –** Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts. • **WHST.11-12.2.D –** Use precise language, domain-specific vocabulary and techniques such as metaphor, simile, and analogy to manage the complexity of the topic; convey a knowledgeable stance in a style that responds to the discipline and context as well as to the expertise of likely readers. • **WHST.11-12.2.E –** Provide a concluding statement or section that follows from and supports the information or explanation provided (e.g., articulating implications or the significance of the topic).

Production and Distribution of Writing	• **WHST.11-12.4 –** Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. • **WHST.11-12.5 –** Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. • **WHST.11-12.6 –** Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.
Research to Build and Present Knowledge	• **WHST.11-12.7 –** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. • **WHST.11-12.8 –** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. • **WHST.11-12.9 –** Draw evidence from informational texts to support analysis, reflection, and research.
Range of Writing	• **WHST.11-12.10 –** Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Essential Questions

1. What is research?
2. How do I select a research project that interests me?
3. How do I write a research question?
4. What materials need to be included in a research proposal?
5. How are control and variable factors identified in research?
6.
7. How do I write a research paper?
8. How is the quality of research determined?
9. What is an abstract?
10. How do I prepare a research poster?
11. How are research data and conclusions shared with others?

Lesson 5.2 From Lab to Production

Concepts	**Performance Objectives**
Students will know and understand	*Students will learn concepts by doing*
1. The genome of multiple organisms can be analyzed in order to understand genetic variations.	• Use web-based resources to find information on the genetic sequence of a protein. (Activity 5.2.1)
2. Regulatory agencies monitor research and development, production, and use of biotech products in order to ensure safety for consumers and the environment.	• Determine the influence of governmental regulatory agencies. (Project 5.2.2) • Write a case study pertaining to a biotechnological application and the role of governmental agencies in determining the safety of the application. (Project 5.2.2)

3. Results of research undergo multiple steps and trials before reaching consumers.	• Develop a model depicting the steps from laboratory research through production to end use of a biotechnology. (Project 5.2.3)
4. Ethical questions surrounding applications of biotechnology, which generate discussions and varying opinions, are based on personal feelings and beliefs.	• Review their ethical perspectives of biotechnological practices and reflect on how their opinions have developed over the length of the course. (Activity 5.2.4)
5. Biotechnology is a fast growing industry with many emerging technologies and future career opportunities.	• Write a letter outlining their vision for future biotechnological innovations and practices. (Problem 5.2.5)

National AFNR Common Career Technical Core Standards Alignment

Career Ready Practices
2. Apply appropriate academic and technical skills.
• CRP.02.01: Use strategic thinking to connect and apply academic learning, knowledge and skills to solve problems in the workplace and community.
• CRP.02.02: Use strategic thinking to connect and apply technical concepts to solve problems in the workplace and community.
4. Communicate clearly, effectively and with reason.
• CRP.04.02: Produce clear, reasoned and coherent written and visual communication in formal and informal settings.
5. Consider the environmental, social and economic impacts of decisions.
• CRP.05.01: Assess, identify and synthesize the information and resources needed to make decisions that positively impact the workplace and community.
6. Demonstrate creativity and innovation.
• CRP.06.01: Synthesize information, knowledge and experience to generate original ideas and challenge assumptions in the workplace and community.
7. Employ valid and reliable research strategies.
• CRP.07.01: Select and implement reliable research processes and methods to generate data for decision-making in the workplace and community.
Agriculture, Food, and Natural Resources Career Cluster
1. Analyze how issues, trends, technologies and public policies impact systems in the Agriculture, Food & Natural Resources Career Cluster.
• AG 1.1: Explain how regulations and major laws impact management of AFNR activities.
• AG 1.2: Describe current issues impacting AFNR activities.
• AG 1.3: Identify, organize alternatives, and evaluate public policy issues related to AFNR.
• AG 1.6: Recognize the historical, social, cultural and potential applications of biotechnology on AFNR activities.
• AG.1.7: Demonstrate the application of biotechnology to AFNR activities.
5. Describe career opportunities and means to achieve those opportunities in each of the AFNR career pathways.
• AG.5.3: Provide examples and descriptions of various careers in each of the AFNR pathways.
Agribusiness Systems Career Pathway (AG-BIZ)
4. Develop a business plan for an AFNR enterprise or business unit.
• AG-BIZ 4.1: Identify strategies to manage or mitigate risk.
• AG-BIZ 4.2: Develop business goals and strategies that capitalize on opportunities in an AFNR market.

Biotechnology Systems Career Pathway Content Standards
BS.01: Assess factors that have influenced the evolution of biotechnology in agriculture (e.g., historical events, societal trends, ethical and legal implications, etc.).
• BS.01.01: Investigate and explain the relationship between past, current and emerging applications of biotechnology in agriculture (e.g., major innovators, historical developments, potential applications of biotechnology, etc.).
• BS.01.02: Evaluate the scope and implications of regulatory agencies on applications of biotechnology in agriculture and protection of public interests (e.g., health, safety, environmental issues, etc.).
• BS.01.03: Analyze the relationship and implications of bioethics, laws and public perceptions on applications of biotechnology in agriculture (e.g., ethical, legal, social, cultural issues).
BS.02: Demonstrate proficiency by safely applying appropriate laboratory skills to complete tasks in a biotechnology research and development environment (e.g., standard operating procedures, record keeping, aseptic technique, equipment maintenance, etc.).
• BS.02.01: Read, document, evaluate and secure accurate laboratory records of experimental protocols, observations and results.

Next Generation Science Standards Alignment

Disciplinary Core Ideas	
Engineering, Technology, and the Application of Science	
ETS1: Engineering Design	
ETS1.B: Developing Possible Solutions	• When evaluating solutions, it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts. • Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs.

Science and Engineering Practices	
Asking Questions and Defining Problems	Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. • Ask questions that arise from careful observation of phenomena, or unexpected results ▪ to clarify and/or seek additional information. ▪ that arise from examining models or a theory, to clarify and/or seek additional information and relationships. ▪ to determine relationships, including quantitative relationships, between independent and dependent variables. ▪ to clarify and refine a model, an explanation, or an engineering problem. • Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations.
Developing and Using Models	Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). • Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria. • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
Analyzing and Interpreting Data	Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
Constructing Explanations and Designing Solutions	Constructing explanations and designing solutions in 9–12 builds on K– 8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. • Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.

	• Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.
Engaging in Argument from Evidence	Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. • Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions. • Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.
Obtaining, Evaluating, and Communicating Information	Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. • Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

Crosscutting Concepts	
Systems and System Models	A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.
	• Systems can be designed to do specific tasks. • Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Understandings about the Nature of Science	
Scientific Investigations Use a Variety of Methods	• New technologies advance scientific knowledge. • Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings.
Science Addresses Questions About the Natural and Material World.	• Not all questions can be answered by science. • Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. • Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. • Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues.

Common Core State Standards for English Language Arts

CCSS: English Language Arts Standards » Science & Technical Subjects » Grade 11-12	
Key Ideas and Details	• **RST.11-12.2 –** Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
Range of Reading and Level of Text Complexity	• **RST.11-12.10 –** By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently.

CCSS: English Language Arts Standards » Writing » Grade 11-12	
Text Types and Purposes	**WHST.11-12.2 –** Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. • **WHST.11-12.2.A –** Introduce a topic and organize complex ideas, concepts, and information so that each new element builds on that which precedes it to create a unified whole; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension. • **WHST.11-12.2.B –** Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic. • **WHST.11-12.2.C –** Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts. • **WHST.11-12.2.D –** Use precise language, domain-specific vocabulary and techniques such as metaphor, simile, and analogy to manage the complexity of the topic; convey a knowledgeable

	stance in a style that responds to the discipline and context as well as to the expertise of likely readers. • **WHST.11-12.2.E –** Provide a concluding statement or section that follows from and supports the information or explanation provided (e.g., articulating implications or the significance of the topic).
Production and Distribution of Writing	• **WHST.11-12.4 –** Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. • **WHST.11-12.5 –** Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. • **WHST.11-12.6 –** Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.
Research to Build and Present Knowledge	• **WHST.11-12.7 –** Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. • **WHST.11-12.8 –** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.
Range of Writing	• **WHST.11-12.10 –** Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Essential Questions

1. What is bioinformatics?
2. How can I use bioinformatics to further my understanding of a genome?
3. What is a regulatory agency?
4. What agencies regulate biotechnology in the United States?
5. How do I write a case study?
6. What are the steps required for a new technology to reach the marketplace?
7. How do researchers decide which technologies to develop and market?
8. How do personal beliefs influence acceptance of biotechnology?
9. How have my personal beliefs changed based on what I have learned in this course?
10. How will biotechnology influence my future?
11. Where will biotechnological advances go in the coming years?