

Agriculture, Food, and Natural Resources (AFNR) Frameworks 2021

Section 10 – Biotechnology Systems (BS) Pathway Frameworks

Introduction

The Biotechnology Systems (BS) Career Pathway encompasses the study of using data and scientific techniques to solve problems concerning living organisms with an emphasis on applications to agriculture, food, and natural resource (AFNR) systems. Students completing a program of study in this pathway will demonstrate competence in the application of principles and techniques for the development, application, and management of biotechnology in the context of AFNR.

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Recommended BS Courses and Pathway Sequence

Students concentrating on the BS pathway should complete a sequence of at least two courses within the following course offerings based their career goals and interests.

Introductory Courses	Intermediate Courses	Advanced Courses
01 Principles of Ag., Food, and Natural Resources	85 Animal and Plant Biotechnology	13 Agricultural Education, Research, and Development
02 Advanced Principles of Ag., Food, and Natural Resources	86 Advanced Animal and Plant Biotechnology	90 Specialty and Emerging Biotechnology Systems Topics
03 Principles of AFNR Biology (Science-Elective Credit)	87 Agricultural Biotechnology and Biology (Science-Elective Credit)	93 Extended/ Summer AFNR Work-Based Learning (SAE) and Leadership (FFA)
04 Advanced Principles of AFNR Biology (Science-Elective Credit)	88 Advanced Agricultural Biotechnology and Biology (Science-Elective Credit)	94 Agricultural Leadership Development
	89 Biofuels, Bioproducts, and Bioengineering	95 Agricultural Career Seminar
		96 Advanced Agricultural Career Seminar
		97 AFNR Work Experience: Immersion SAE (Adv. Internship/Placement, Entrepreneurship, Research)

Recommended Work-Based Learning (WBL) and SAEs within BS

A Supervised Agricultural Experience (SAE) is a student-led, instructor-supervised, Work-Based Learning (WBL) experience that results in measurable outcomes within a predefined, agreed upon set of AFNR Technical Standards and Career Ready Practices aligned to a Career Plan of study. SAE teaches technical skills and knowledge within the psychomotor domain of learning. SAE includes both experiential learning (i.e., pre-WBL) and WBL (federally defined as sustained interactions with industry or community professionals in real workplace settings, to the extent practicable, or simulated environments, at an educational institution that foster in-depth, firsthand engagement with the tasks required in a given career field, that are aligned to curriculum and instruction; Sec. 3 [20 U.S.C. 2302] 55).

SAE/WBL is a required component of an AFNR program, first established in the Smith-Hughes Act (1917) and reinforced in each of the federal Perkins Career and Technical Education (CTE) Acts (1984 – I; 1990 – II; 1998 – III; 2006 – IV; 2018 – V, Public Law No. 115-224). Minnesota also requires WBL/SAE as a component of CTE Program Approval (Minn. R. 3505). Table 1 has example SAE opportunities within this pathway, as defined by the National Council for AFNR Education, Perkins V legislation, and the Minnesota Department of Education.

Table 1. Examples of WBL/SAE Curricula and Programs within BS

SAE Program Area	Examples, Non-Exhaustive
Experiential Learning (Foundational SAE; Pre-WBL)	• Career exploration • Job shadowing a biological technician • Interview a naturalist • Field trip to local research university
Internship (Placement SAE; Immersion WBL)	• Working for a biotechnology company • Working for the natural resources and conservation district • Working for a food testing laboratory • Maintain laboratory equipment aligned to standard procedures
Apprenticeship (Placement SAE; Immersion WBL)	• More than 450 hours in an internship, combined with coursework • Contact the Minnesota Department of Education (MDE) for support
Entrepreneurship (Entrepreneurship SAE; Immersion WBL)	• Produce plants using plant-breeding techniques • Conduct habitat restoration • Sell safely processed food items at the local Farmer’s Market (e.g., fermented, preserved)
Research (Research SAE; Immersion WBL)	• Public perceptions of scientific arguments in biotechnology • Evaluate plant propagation techniques • Evaluate biofuels
School-Based Enterprise (School-Based SAE; Simulated WBL)	• Greenhouse Management/Operations SBE WBL • Aquaculture Operations SBE WBL • Forest/Natural Resources Operations SBE WBL
FFA Work-Based Learning and SAE Proficiency Award Areas	• Agricultural Processing • Nursery Operations • Veterinary Science

Recommended Social-Emotional Learning (SEL) and FFA Opportunities within BS

The National FFA Organization (FFA) is a student-led, instructor-supervised, Career and Technical Student Organization (CTSO) that results in measurable outcomes within a predefined, agreed upon set of AFNR Social-Emotional Standards and Career Ready Practices aligned to a Career Plan of study. FFA teaches social-emotional and leadership skills and knowledge within the affective domain of learning. FFA includes programs that provide essential employability skills such as critical thinking, consensus building, communication, teamwork, and leadership. FFA was founded in 1928 and is federally defined as intracurricular (i.e., within the curriculum; cf. extracurricular: external, co-curricular: alongside) and an integral part (i.e., necessary to form the whole) of School-Based AFNR Education (Public Law No. 116-7).

Leadership/FFA is a required component of an AFNR program, formalized in the FFA Federal Charter in 1950 (Public Law No. 116-7) and reinforced in federal Perkins CTE Acts (1984 – I; 1990 – II; 1998 – III; 2006 – IV; 2018 – V, Public Law No. 115-224). Minnesota also requires leadership/FFA as a component of CTE Program Approval (Minn. R. 3505). Table 2 has example FFA opportunities with this pathway, as defined by the National Council for AFNR Education, Perkins V legislation, Department of Education, and the Minnesota FFA Association.

Table 2. Examples of SEL/FFA Curricula and Programs within BS

FFA Program Area	Examples, Non-Exhaustive
Student Development Programs (Growing Leaders)	• Officer and committee leadership opportunities • Agriscience fair or SAE open house • Career day/guest speaker
Community Development/Service (Building Communities)	• Collect used pesticide containers • Assist local organizations with GMO field trials • Donate processed produce from the school garden following all approved food safety measures
Literacy, Advocacy, and Safety (Strengthening Agriculture)	• Agricultural Issues presentation on bioremediation • Learn about safe handling of biological and chemical waste in agriculture • Attend demonstration of genetic testing on livestock
Conferences, Conventions, and Banquets	• InTENse • World Food Prize conference • Horizon conference
Career Development Events (CDE)	• Agricultural Mechanics and Technology • Agronomy • Food Science • Meats • Milk Quality and Products • Soils • Veterinary Science
Leadership Development Events (LDE)	• Agricultural Issues Forum • Marketing Plan • Prepared Public Speaking • Extemporaneous Speaking

MN.BS.01: Biotechnology Ethics and Policy

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

Performance Indicator MN.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).

Introductory Course Benchmarks	Intermediate Course Benchmarks	Advanced Course Benchmarks
BS.01.01.01.a. Research and summarize the evolution of biotechnology in agriculture.	BS.01.01.01.b. Analyze the developmental progression of biotechnology and the evolution of scientific knowledge.	BS.01.01.01.c. Evaluate and explain how scientists use the scientific method to build upon previous findings in current and emerging research.
BS.01.01.02.a. Examine and categorize current applications and gains achieved in applying biotechnology to agriculture.	BS.01.01.02.b. Assess and summarize current work in biotechnology being done to add value to agricultural and society.	BS.01.01.02.c. Evaluate the outcomes and impacts of biotechnology on the globalization of agriculture.
BS.01.01.03.a. Distinguish between current and emerging applications of biotechnology in agriculture.	BS.01.01.03.b. Analyze and document emerging problems and issues associated with agricultural biotechnology.	BS.01.01.03.c. Design a potential application of biotechnology to meet emerging agricultural and societal needs.
BS.01.01.04.a. Compare and contrast the benefits and risks of biotechnology compared with alternative approaches to improving agriculture.	BS.01.01.04.b. Assess the benefits and risks associated with using biotechnology to improve agriculture.	BS.01.01.04.c. Evaluate the short-term and long-term benefits and risks.

MN.BS.01: Biotechnology Ethics and Policy, Continued

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

Performance Indicator MN.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, and environmental issues).

Introductory Course Benchmarks	Intermediate Course Benchmarks	Advanced Course Benchmarks
BS.01.02.01.a. Compare and contrast differences between regulatory systems worldwide.	BS.01.02.01.b. Assess and summarize the role and scope of agencies that regulate biotechnology.	BS.01.02.01.c. Explain and critique a decision made by a major agency that regulates agricultural biotechnology.
BS.01.02.02.a. Research and document major regulatory issues related to biotechnology in agriculture.	BS.01.02.02.b. Analyze the impact major regulatory issues have on public acceptance of biotechnology in agriculture.	BS.01.02.02.c. Critique and propose a solution for a major regulatory issue pertaining to biotechnology in agriculture.
BS.01.02.03.a. Explain the relationship between regulatory agencies and the protection of public interests such as health, safety, and the environment.	BS.01.02.03.b. Research and summarize factors and data that regulatory agencies use to evaluate the potential risks a new application of biotechnology may pose to health, safety, and the environment.	BS.01.02.03.c. Evaluate data to determine if new technologies present a major regulatory issue to health, safety, and the environment.

MN.BS.01: Biotechnology Ethics and Policy, Continued

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

Performance Indicator MN.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, and cultural issues).

Introductory Course Benchmarks	Intermediate Course Benchmarks	Advanced Course Benchmarks
BS.01.03.01.a. Research and summarize the emergence, evolution and implications of bioethics associated with biotechnology in agriculture.	BS.01.03.01.b. Analyze the implications bioethics may have on future advancements in AFNR.	BS.01.03.01.c. Devise and support an argument for or against an ethical issue associated with biotechnology in agriculture.
BS.01.03.02.a. Research and summarize legal issues related to biotechnology in agriculture (e.g., protection of intellectual property through patents, copyright, trademarks).	BS.01.03.02.b. Determine the significance and impacts of legal issues related to biotechnology in agriculture.	BS.01.03.02.c. Propose a solution for a legal issue associated with biotechnology in agriculture.
BS.01.03.03.a. Research and summarize public perceptions of biotechnology in agriculture (e.g., social issues, cultural issues).	BS.01.03.03.b. Analyze the impact of public perceptions on the application of biotechnology in different AFNR systems.	BS.01.03.03.c. Design studies to examine public perceptions of scientifically based arguments regarding biotechnology in agriculture and reflect on the reasons why the public may support or resist significant breakthroughs using biotechnology.

MN.BS.02: Scientific Applications within Biotechnology

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).

Performance Indicator MN.BS.02.01

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).

Introductory Course Benchmarks	Intermediate Course Benchmarks	Advanced Course Benchmarks
BS.02.01.01.a. Compare and contrast common record-keeping methods used in a laboratory (e.g., paper notebook, electronic notebook).	BS.02.01.01.b. Maintain and interpret laboratory records documented in a laboratory to ensure data accuracy and integrity (e.g., avoid bias, record any conflicts of interest, avoid misinterpreted results).	BS.02.01.01.c. Evaluate the strengths and weaknesses of using research documentation and propose improvements to ensure study reproduction and utility in future studies.
BS.02.01.02.a. Research and summarize the need for data and information security in a laboratory and demonstrate best practices.	BS.02.01.02.b. Assess when security procedures for data and information collected in a laboratory should be implemented.	BS.02.01.02.c. Devise a strategy for ensuring the security of data and information collected in a laboratory.
BS.02.01.03.a. Evaluate the role of bioinformatics in agriculture and summarize the types of databases that are available (e.g., genomic, transcriptomics).	BS.02.01.03.b. Analyze and document the security procedures for data collected using bioinformatics.	BS.02.01.03.c. Critique an application of bioinformatics to solve an agricultural issue and recommend procedures.

MN.BS.02: Scientific Applications within Biotechnology, Continued

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).

Performance Indicator MN.BS.02.02

Implement standard operating procedures for the proper maintenance, use and sterilization of equipment in a laboratory.

Introductory Course Benchmarks	Intermediate Course Benchmarks	Advanced Course Benchmarks
BS.02.02.01.a. Identify, interpret, and implement standard operating procedures for laboratory equipment.	BS.02.02.01.b. Develop a maintenance program for laboratory equipment based upon the standard operating procedures.	BS.02.02.01.c. Perform ongoing maintenance of laboratory equipment according to the standard operating procedures (e.g., calibration, testing).
BS.02.02.02.a. Categorize and identify laboratory equipment according to its purpose in scientific research.	BS.02.02.02.b. Manipulate basic laboratory equipment and measurement devices (e.g., water bath, electrophoresis equipment, micropipettes, laminar flow hood).	BS.02.02.02.c. Operate advanced laboratory equipment and measurement devices (e.g., thermal cycler, imaging system).
BS.02.02.03.a. Differentiate between sterilization techniques for equipment in a laboratory (e.g., media bottles vs. laminar flow hood).	BS.02.02.03.b. Create a plan for sterilizing equipment in a laboratory according to standard operating procedures.	BS.02.02.03.c. Perform sterilization techniques for equipment in a laboratory using standard operating procedures.

MN.BS.02: Scientific Applications within Biotechnology, Continued

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).

Performance Indicator MN.BS.02.03

Apply standard operating procedures for the safe handling of biological and chemical materials in a laboratory.

Introductory Course Benchmarks	Intermediate Course Benchmarks	Advanced Course Benchmarks
BS.02.03.01.a. Classify and document basic aseptic techniques in the laboratory.	BS.02.03.01.b. Demonstrate advanced aseptic techniques in the laboratory (e.g., sterile work area, sterile handling, personal hygiene).	BS.02.03.01.c. Conduct assays and experiments under aseptic conditions.
BS.02.03.02.a. Examine and implement standard operating procedures for the use of biological materials according to directions and their classification (e.g., proper handling of bacteria or DNA before, during and after use).	BS.02.03.02.b. Analyze and select an appropriate standard operating procedure for working with biological materials based upon their classification.	BS.02.03.02.c. Create a standard operating procedure for a biological process.
BS.02.03.03.a. Categorize and label the types of solutions that are commonly prepared in a laboratory (e.g., buffers, reagents, media).	BS.02.03.03.b. Formulate and prepare solutions using standard operating procedures (e.g., proper labeling, storage).	BS.02.03.03.c. Verify the physical properties of solutions (e.g., molarity, percent mass/volume, dilutions).

MN.BS.02: Scientific Applications within Biotechnology, Continued

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).

Performance Indicator MN.BS.02.04

Safely manage and dispose of biological materials, chemicals, and wastes according to standard operating procedures.

Introductory Course Benchmarks	Intermediate Course Benchmarks	Advanced Course Benchmarks
BS.02.04.01.a. Classify different types of personal protective equipment and demonstrate how to properly utilize the equipment.	BS.02.04.01.b. Assess the need for personal protective equipment in a variety of situations and select the appropriate equipment to wear when working with biological and chemical materials.	BS.02.04.01.c. Evaluate the benefits and limitations of personal protective equipment.
BS.02.04.02.a. Classify and describe hazards associated with biological and chemical materials.	BS.02.04.02.b. Inventory biological and chemical materials and maintain accurate records of supplies and expiration dates.	BS.02.04.02.c. Create a plan for stocking and maintaining supplies of biological and chemical materials in a laboratory.
BS.02.04.03.a. Summarize what happens to waste after it leaves the laboratory and identify opportunities to reduce waste and unnecessary costs.	BS.02.04.03.b. Perform waste disposal according to the standard operating procedures.	BS.02.04.03.c. Propose a management plan to reduce laboratory waste and prevent ecological or health problems related to waste disposal.

MN.BS.02: Scientific Applications within Biotechnology, Continued

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).

Performance Indicator MN.BS.02.05

Examine and perform scientific procedures using microbes, DNA, RNA, and proteins in a laboratory.

Introductory Course Benchmarks	Intermediate Course Benchmarks	Advanced Course Benchmarks
BS.02.05.01.a. Differentiate types of organisms and demonstrate safe handling to maintain organism purity and personal safety (e.g., plant and animal tissue, cell cultures, microbes).	BS.02.05.01.b. Characterize the physical and biological properties of organisms.	BS.02.05.01.c. Isolate, maintain, quantify, and store cell cultures according to standard operating procedures.
BS.02.05.02.a. Compare and contrast the structures of DNA and RNA and investigate how genotype influences phenotype.	BS.02.05.02.b. Analyze and interpret the molecular basis for heredity and the tools and techniques used in DNA and RNA manipulations.	BS.02.05.02.c. Evaluate factors that influence gene expression.
BS.02.05.03.a. Extract and purify DNA and RNA according to standard operating procedures.	BS.02.05.03.b. Perform electrophoretic techniques and interpret electrophoresis fragmentation patterns (e.g., gel electrophoresis, southern blotting).	BS.02.05.03.c. Manipulate and analyze DNA and RNA through advanced scientific procedures [e.g., southern blotting; cloning; polymerase chain reaction (PCR); reverse transcription polymerase chain reaction (RT-PCR)].
BS.02.05.04.a. Examine and document the role and applications of proteins in agricultural biotechnology.	BS.02.05.04.b. Demonstrate protein separation techniques and interpret the results.	BS.02.05.04.c. Evaluate the biochemical properties of proteins to explain their function and predict potential uses.
BS.02.05.05.a. Synthesize the relationship between proteins, enzymes, and antibodies.	BS.02.05.05.b. Analyze and document how antibodies are formed and describe how they can be used in agricultural biotechnology.	BS.02.05.05.c. Use antibodies to detect and quantify antigens by conducting an Enzyme-Linked Immunosorbent Assay (ELISA).

MN.BS.03: Biotechnology Techniques

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

Performance Indicator MN.BS.03.01

Apply biotechnology principles, techniques, and processes to create transgenic species through genetic engineering.

Introductory Course Benchmarks	Intermediate Course Benchmarks	Advanced Course Benchmarks
BS.03.01.01.a. Summarize biological, social, agronomic, and economic reasons for genetic modification of eukaryotes.	BS.03.01.01.b. Analyze and document the processes and describe the techniques used to produce transgenic eukaryotes (e.g., microbial synthetic biology, gene knockout therapy, traditional gene insertion).	BS.03.01.01.c. Design and conduct experiments to evaluate an existing transgenic eukaryote.
BS.03.01.02.a. Summarize the process of transformation of eukaryotic cells with transgenic DNA.	BS.03.01.02.b. Assess and argue the pros and cons of transgenic species in agriculture.	BS.03.01.02.c. Transform plant or animal cells by performing a cellular transformation.
BS.03.01.03.a. Analyze the benefits and risks associated with the use of biotechnology to increase productivity and improve quality of living species (e.g., plants, animals such as aquatic species).	BS.03.01.03.b. Research and evaluate genetic engineering procedures used in the production of living species.	BS.03.01.03.c. Conduct field or clinical trials for genetically modified species.
BS.03.01.04.a. Define and summarize epigenetics and synthesize the relationship between mutation, migration, and evolution of transgenes in the environment.	BS.03.01.04.b. Analyze data to identify changes and patterns of transgenic species in the environment.	BS.03.01.04.c. Conduct studies to track the movement of transgenes in the environment.

MN.BS.03: Biotechnology Techniques, Continued

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

Performance Indicator MN.BS.03.02

Apply biotechnology principles, techniques, and processes to enhance the production of food through the use of microorganisms and enzymes.

Introductory Course Benchmarks	Intermediate Course Benchmarks	Advanced Course Benchmarks
BS.03.02.01.a. Summarize reasons for detecting microbes and identify sources of microbes.	BS.03.02.01.b. Assess and describe the use of biotechnology to detect microbes.	BS.03.02.01.c. Design and perform an assay to detect a target microorganism in food, water, or the environment.
BS.03.02.02.a. Examine enzymes, the changes they cause and the physical and chemical parameters that affect enzymatic reactions (e.g., food, cellulosic bioenergy).	BS.03.02.02.b. Analyze processes by which enzymes are produced through biotechnology.	BS.03.02.02.c. Conduct studies using scientific techniques to improve or discover enzymes for use in biotechnology (e.g., microbial strain selection).
BS.03.02.03.a. Identify and categorize foods produced through the use of biotechnology (e.g., fermentation) to change the chemical properties of food for an intended purpose (e.g., create desirable nutritional profile, preservation, flavor).	BS.03.02.03.b. Compare and contrast the effectiveness, purpose, and outcomes associated with biotechnology as well as conventional processes used in food processing.	BS.03.02.03.c. Process food using biotechnology to achieve an intended purpose (e.g., preservation, flavor enhancement).

MN.BS.03: Biotechnology Techniques, Continued

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

Performance Indicator MN.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).

Introductory Course Benchmarks	Intermediate Course Benchmarks	Advanced Course Benchmarks
BS.03.03.01.a. Examine the consequences of agricultural practices on natural populations.	BS.03.03.01.b. Analyze how biotechnology can be used to monitor the effects of agricultural practices on natural populations.	BS.03.03.01.c. Evaluate the impact of modified organisms on the natural environment.
BS.03.03.02.a. Define and summarize industrial biotechnology and categorize the benefits and risks associated with its use in manufacturing (e.g., fabrics, plastics).	BS.03.03.02.b. Apply the processes used in the production of molecules for use in industrial applications.	BS.03.03.02.c. Monitor and evaluate processes used in the synthesis of a molecule.
BS.03.03.03.a. Research and summarize the potential applications of bioprospecting in biotechnology and agriculture.	BS.03.03.03.b. Assess and document the pros and cons of bioprospecting to achieve a research or product development objective.	BS.03.03.03.c. Propose opportunities to use bioprospecting after weighing the short-term and long-term impacts on the environment.

MN.BS.03: Biotechnology Techniques, Continued

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

Performance Indicator MN.BS.03.04

Apply biotechnology principles, techniques, and processes to enhance plant and animal care and production (e.g., selective breeding, pharmaceuticals, biodiversity).

Introductory Course Benchmarks	Intermediate Course Benchmarks	Advanced Course Benchmarks
BS.03.04.01.a. Research and describe the aims and techniques involved in selective plant-breeding process.	BS.03.04.01.b. Choose techniques and identify tools used to monitor and direct plant breeding.	BS.03.04.01.c. Perform plant-breeding techniques (e.g., plant tissue culture).
BS.03.04.02.a. Examine and classify biotechnology processes applicable to animal health (e.g., genetic testing).	BS.03.04.02.b. Assess the benefits, risks and opportunities associated with using biotechnology to promote animal health.	BS.03.04.02.c. Design animal-care protocols to ethically monitor and promote animal systems associated with biotechnology.
BS.03.04.03.a. Research and categorize the types of pharmaceuticals developed for animals and humans through biotechnology.	BS.03.04.03.b. Distinguish the difference between plant-based and animal-based pharmaceuticals and describe their role in agriculture.	BS.03.04.03.c. Evaluate the process used to produce pharmaceuticals from transgenic organisms (e.g., hormones for animals).
BS.03.04.04.a. Summarize the need for global biodiversity and applications of biotechnology to reduce threats to biodiversity.	BS.03.04.04.b. Assess whether current threats to biodiversity will have an unsustainable impact on human populations.	BS.03.04.04.c. Select and utilize techniques to measure biodiversity in a population.

MN.BS.03: Biotechnology Techniques, Continued

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

Performance Indicator MN.BS.03.05

Apply biotechnology principles, techniques, and processes to produce biofuels (e.g., fermentation, transesterification, methanogenesis).

Introductory Course Benchmarks	Intermediate Course Benchmarks	Advanced Course Benchmarks
BS.03.05.01.a. Examine and synthesize the need for biofuels (e.g., cellulosic bioenergy).	BS.03.05.01.b. Analyze the impact of the production and use of biofuels on the environment.	BS.03.05.01.c. Evaluate and support how biofuels could solve a global issue (e.g., environmental, agricultural).
BS.03.05.02.a. Differentiate between biomass and sources of biomass.	BS.03.05.02.b. Assess the characteristics of biomass that make it useful for biofuels production.	BS.03.05.02.c. Conduct a review of the technologies used to create biofuels from biomass and weigh the pros and cons of each method.
BS.03.05.03.a. Research and explain the process of fermentation and its potential applications.	BS.03.05.03.b. Correlate the relationship between fermentation and the process used to produce alcohol from biomass.	BS.03.05.03.c. Produce alcohol and co-products from biomass.
BS.03.05.04.a. Define and summarize the process of transesterification and its potential applications.	BS.03.05.04.b. Analyze and document the process used to produce biodiesel from biomass.	BS.03.05.04.c. Produce biodiesel and co-products from biomass.
BS.03.05.05.a. Examine the process of methanogenesis and its potential applications.	BS.03.05.05.b. Analyze and describe the process used to produce methane from biomass.	BS.03.05.05.c. Produce methane and co-products from biomass.

MN.BS.03: Biotechnology Techniques, Continued

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

Performance Indicator MN.BS.03.06

Apply biotechnology principles, techniques, and processes to improve waste management (e.g., genetically modified organisms, bioremediation).

Introductory Course Benchmarks	Intermediate Course Benchmarks	Advanced Course Benchmarks
BS.03.06.01.a. Compare and contrast the use of natural organisms and genetically engineered organisms in the treatment of wastes.	BS.03.06.01.b. Analyze the process by which organisms are genetically engineered for waste treatment.	BS.03.06.01.c. Conduct studies to evaluate the treatment of a waste product using a genetically engineered organism.
BS.03.06.02.a. Summarize the purpose of microorganisms in biological waste management.	BS.03.06.02.b. Assess and describe the processes involved in biotreatment of biological wastes.	BS.03.06.02.c. Monitor and evaluate the treatment of biological wastes with microorganisms.
BS.03.06.03.a. Analyze the role of microorganisms in industrial chemical waste treatment.	BS.03.06.03.b. Evaluate and describe the processes involved in biotreatment of industrial chemical wastes.	BS.03.06.03.c. Monitor and review the treatment of industrial chemical wastes with microorganisms.
BS.03.06.04.a. Provide examples of instances in which bioremediation can be applied to clean up environmental contaminants.	BS.03.06.04.b. Analyze and summarize the risks and benefits of using biotechnology for bioremediation.	BS.03.06.04.c. Design a bioremediation project including plans to effectiveness of the effort.

Primary AFNR Pathways that Align with BS

Section 4 – Animal Systems (AS) Pathway Frameworks.....53

A primary AFNR pathway encompassing the study of animal systems, including content areas such as life processes, health, nutrition, genetics, management, and processing, as applied to small animals, aquaculture, exotic animals, livestock, dairy, horses and/or poultry. Students completing a program of study in this pathway will demonstrate competence in the application of principles and techniques for the development, application, and management of animal systems in AFNR settings.

Section 5 – Plant Systems (AS) Pathway Frameworks..... 73

A primary AFNR pathway encompassing the study of plant life cycles, classifications, functions, structures, reproduction, media, and nutrients, as well as growth and cultural practices through the study of crops, turf grass, trees, shrubs, and ornamental plants. Students completing a program of study in this pathway will demonstrate competence in the application of principles and techniques for the development, application, and management of plant systems in AFNR settings.

Section 6 – Natural Resources & Environmental Service Systems (NRES) Pathway Frameworks..... 89

A primary AFNR pathway encompassing the study of the management, protection, enhancement, and improvement of soil, water, wildlife, forests, and air as natural resources as well as the study of systems, instruments, and technology used to monitor and minimize the impact of human activity on environmental systems. Students completing a program of study in this pathway will demonstrate competence in the application of principles and techniques for the development, application, and management of natural resource and environmental service systems in AFNR settings.

Section 7 – Power, Structural, and Technical Systems (PST) Pathway Frameworks..... 120

A sprimary AFNR pathway encompassing the study of agricultural equipment, power systems, alternative fuel sources, and precision technology, as well as woodworking, metalworking, welding, and project planning for agricultural structures. Students completing a program of study in this pathway will demonstrate competence in the application of principles and techniques for the development, application, and management of power, structural, and technical systems in AFNR settings.