Biotechnology Honors

Unit Title: Unit 1 & 2: The Biotechnology Industry & Laboratory Skills

Stage 1: Desired Results

Standards & Indicators:

NJSLS Science:

- HS-ETS1-1: Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
- HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Science and Engineering Practices(SEP)

- **Using Mathematics and Computational Thinking:** Create and/or use a computational model or simulation of a phenomenon, designed device, or system. (HS-ESTS1-1)
- **Obtaining, Evaluating, and Communicating Information:** Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts. (HS-ESTS1-1)
- **Planning and Carrying Out Investigations** Planning and carrying out 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 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. (HS-ESTS1-2)

Disciplinary Core Ideas (DCI)

- **ETS1.A: Defining and Delimiting Engineering Problems:** Criteria and constraints also include satisfying any requirements set by society, such as taking considerations of risk into account, and they should be quantified to the extent possible. (HS-ESTS1-2)
- **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 and environmental impacts.(HS-ESTS1-1)

Crosscutting Concepts (CCC)

- **Scale, Proportion, and Quantity:** In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.(HS-ESTS1-2)
- **Application:** Conceptualizing macro-to-micro structures, cell dimensions, microfluidics, and the nanometer scale of biomolecules. (HS-ESTS1-1)
- **Systems and System Models:** Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the powerful and complex nature of interconnections. (HS-ESTS1-2)

Career Readiness, Life Literacies and Key Skills

Standard	Performance Expectations	Core Ideas
9.4.12.CT.1	Identify problem-solving strategies used in the development of an innovative product or practice (e.g., 1.1.12acc.C1b, 2.2.12.PF.3).	Collaboration with individuals with diverse experiences can aid in the problem-solving process, particularly for global issues where diverse solutions are needed.
9.4.12.TL.1	Assess digital tools based on features such as accessibility options, capacities, and utility for accomplishing a specified task (e.g., W.11-12.6.).	Digital tools differ in features, capacities, and styles. Knowledge of different digital

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		tools is helpful in selecting the best tool for a given task.

Central Idea/Enduring Understanding:	**Essential/Guiding Question:**
● Students formulate an answer to the question "How do the structures of organisms enable life's functions?" ● Students investigate explanations for the structure and functions of cells as the basic unit of life, of hierarchical organization of interacting organ systems, and of the role of specialized cells for maintenance and growth. ● The crosscutting concepts of structure and function, matter and energy, and systems and system models are called out as organizing concepts for the disciplinary core ideas. ● Students use critical reading, modeling, and conducting investigations. Students also use the science and engineering practices to demonstrate understanding of the disciplinary core ideas.	● How do workplace safety protocols protect both the researcher and the ultimate integrity of the scientific data? ● Why is regulatory compliance (such as OSHA and SDS) considered non-negotiable in an industrial biotechnology setting? ● How have historical breakthroughs in biotechnology shaped modern industry practices and societal ethics? ● In what ways does the evolution of biotechnology reflect changing global needs and technological capabilities? ● How do the distinct sectors of biotechnology (R&D, QA/QC, Manufacturing, Regulatory Affairs) collaborate to bring a single product to market? ● What core competencies and professional standards define a competitive workforce candidate in the modern biotech landscape? ● Why is meticulous documentation considered the legal and scientific foundation of biotechnology research? ● How does adhering to Good Laboratory Practices (GLP) safeguard intellectual property and ensure the reproducibility of discoveries? ● Why is absolute mathematical precision critical when translating biological concepts from the nanoscale (10^{-9}) to macro-scale industrial production? ● How can a minor decimal or unit conversion error impact experimental outcomes, financial bottom lines, and consumer safety in biomanufacturing?
Content:	**Skills(Objectives):**
● Science Safety ● Biotechnology Timeline ● Jobs in Biotechnology ● Laboratory Notebook Standards ● Laboratory Equipment ● Micropipetting Technique ● Preparation and Dilution of Laboratory Solutions (Molarity, %, v/v, w/v) ● Significant Digits, Metric Conversion, Nanoscaling	● Evaluate Safety Data Sheets (SDS) to identify chemical hazards, handling protocols, and emergency procedures. ● Select and properly utilize appropriate Personal Protective Equipment (PPE) and engineering controls in accordance with OSHA standards. ● Demonstrate proper emergency response procedures, including the correct use of eyewash stations, safety showers, and fire suppression equipment. ● Evaluate the societal, economic, and ethical impacts of historical versus modern biotechnological advancements. ● Differentiate between the core sectors of the biotech industry, including Research & Development (R&D), Quality Assurance/Quality

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	Control (QA/QC), Manufacturing, and Regulatory Affairs. ● Map out potential career pathways, required credentials, and professional responsibilities within a corporate or academic biotechnology structure. ● Maintain a legally defensible lab notebook that strictly adheres to Good Laboratory Practices (GLP) and industry documentation standards. ● Document experimental procedures, deviations, and data in real-time with sufficient clarity for an independent researcher to replicate the work. ● Apply the rules of significant digits to scientific measurements and calculations to maintain industry-required precision. ● Execute rapid metric conversions and dimensional analysis to accurately prepare solutions and media.Conceptualize and calculate dimensions at the nanoscale (10^{-9}) to analyze macro-to-micro structures in biomanufacturing.

Interdisciplinary Connections:

- **ELA NJSLS**
  - **W.WR.9–10.5.** 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.
  - **SL.UM.9–10.5.** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance findings, reasoning, and evidence and to add interest.
- **Math NJSLS**
  - **MP 4-**Model with mathematics.
  - **N.Q-1**-Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data display

Stage 2: Assessment Evidence

Performance Task(s):	Other Evidence:
● Intro to Biotechnology presentation ○ Difference between biotechnology and other industries ○ Is Biotechnology Good or Bad? The Ethics of Bioengineering ○ Who Uses Biotechnology in Society? ○ Careers in Biotechnology ○ My Favorite Career in Biotechnology ○ Lab Equipment Inquiry Station Activity ○ Making Solutions Lab ○ Micropipetting Lab	● Class discussions ● Writing Exercises ● Making Solutions Quiz ● Micropipetting Technique Quiz

Stage 3: Learning Plan

Learning Opportunities/Strategies:	Resources:
● Team building activities	

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• Cooperative learning activities • Online learning websites • Internet research • Student driven activities	• Textbook: Biotechnology: A Laboratory Skills Course: J. Kirk Brown LGBT and Disabilities Resources: • LGBTQ-Inclusive Lesson & Resources by Garden State Equality and Make it Better for Youth • LGBTQ+ Books DEI Resources: • Learning for Justice • GLSEN Educator Resources • Supporting LGBTQIA Youth Resource List • Respect Ability: Fighting Stigmas, Advancing Opportunities • NJDOE Diversity, Equity & Inclusion Educational Resources • Diversity Calendar

Differentiation *Please note: Teachers who have students with 504 plans that require curricular accommodations are to refer to Struggling and/or Special Needs Section for differentiation

High-Achieving Students	On Grade Level Students	Struggling Students	Special Needs/ELL
Allow the use of technology on assignments Provide web-based projects to further expand class materials Allow students to collaborate in small groups	Provide visual aides Study guides Allow the use of technology on assignments Allow students to collaborate in small groups	Graphic Organizers Shorten assignments Grade for content not spelling and grammar Allow extra time for assignments if student goes to tutoring Provide visual aides Study guides Allow the use of technology on assignments Allow students to collaborate in small groups	Any student requiring further accommodations and/or modifications will have them individually listed in their 504 Plan or IEP. These might include, but are not limited to: breaking assignments into smaller tasks, giving directions through several channels (auditory, visual, kinesthetic, model), and/or small group instruction for reading/writing ELL supports should include, but are not limited to, the following:: Extended time Provide visual aids Repeated directions Differentiate based on proficiency Provide word banks Allow for translators, dictionaries

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Unit Title: Unit 3: Microbiology and Cell Culture

Stage 1: Desired Results

Standards & Indicators:

NJSLS Science:

- HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.
- HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

Science and Engineering Practices(SEP)

- **Planning and Carrying Out Investigations:** Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence... select features of experimental design number of trials, appropriate tools) to ensure revisions in practice are sound. (HS-LS1-2) (HS-LS1-1)
- **Using Mathematics and Computational Thinking:** Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficients) to scientific and engineering questions and problems. (HS-LS1-2) (HS-LS1-1)

Disciplinary Core Ideas (DCI)

- LS1.A: Structure and Function: Systems of specialized cells within organisms help them perform the essential functions of life. Multicellular organisms have a hierarchical structural organization.
- LS1.C: Organization for Matter and Energy Flow in Organisms: Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles.

Crosscutting Concepts (CCC)

- **Scale, Proportion, and Quantity:** Algebraic thinking and analysis for linear and non-linear relationships in systems at different scales are critical components of science and engineering.
- **Structure and Function:** The way an object is shaped or structured determines many of its properties and functions.

Career Readiness, Life Literacies and Key Skills

Standard	Performance Expectations	Core Ideas
9.4.12.CT.1	Identify problem-solving strategies used in the development of an innovative product or practice (e.g., 1.1.12acc.C1b, 2.2.12.PF.3).	Collaboration with individuals with diverse experiences can aid in the problem-solving process, particularly for global issues where diverse solutions are needed.
9.4.12.TL.1	Assess digital tools based on features such as accessibility options, capacities, and utility for accomplishing a specified task (e.g., W.11-12.6.).	Digital tools differ in features, capacities, and styles. Knowledge of different digital tools is helpful in selecting the best tool for a given task.

Central Idea/Enduring Understanding:	Essential/Guiding Question:
● **Structural Classification & Medical Targeting:** Microscopic cellular structures, such as the thickness of a peptidoglycan cell wall, and physiological constraints, like distinct oxygen requirements, dictate how microorganisms are classified, identified, and targeted medically.	● How do microscopic physical structures and environmental requirements dictate our ability to control, target, or exploit microbial systems? ● Why is precise classification the foundational gatekeeper for both patient diagnostics and biotechnological commercialization?

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• **Taxonomic Markers in Industry:** Phenotypic variations in bacterial morphology (e.g., coccus, bacillus, spirillum) and cellular arrangements (e.g., streptococci, staphylococci) serve as primary taxonomic markers and baseline metrics for identifying contamination in biomanufacturing processes. • **Frameworks of Scientific Causation:** Establishing definitive scientific causation between a specific biological agent and a systemic effect requires strict, reproducible experimental frameworks, as historically proven by Koch's Postulates. • **Evolution of Validation Paradigms:** While historical validation frameworks laid the groundwork for modern medicine, biological complexities—such as unculturable pathogens or multi-agent diseases—demand that modern molecular biotechnology expand beyond rigid historical paradigms. • **Predictability of Population Kinetics:** Microbial populations transition through highly predictable mathematical growth phases (lag, log, and stationary), providing engineers with precise mathematical control over biomass accumulation and protein expression.	• What defines a scientifically valid link between a biological cause and an observed effect? • How must scientific frameworks evolve when the limitations of historical methodologies clash with newly discovered biological complexities? • How can predictable growth kinetics and unpredictable genetic mutations simultaneously coexist in an industrial or medical setting?
Content: • Microbiology and Cell Culture (Chapter 3) • Types of Bacteria • Gram staining • Uses of Bacteria and Eukaryotes in Biotechnology • Culturing Bacteria in the Laboratory • Microbiological Techniques • Serial Dilutions • Cell Growth Curve Analysis	**Skills(Objectives):** • Classify unknown bacterial samples by evaluating physical shapes (*coccus, bacillus, spirillum, vibrio, spirochete*) and cellular arrangements (*diplococci, streptococci, staphylococci, streptobacilli*) under high-power oil immersion microscopy. • Differentiate between Gram-positive and Gram-negative bacteria by analyzing variations in their cell wall architectures (thick peptidoglycan vs. outer membrane layer) and predicting their structural responses to standard antibiotics. • Categorize microorganisms based on their metabolic oxygen requirements (*obligate aerobes, obligate anaerobes, facultative anaerobes, and microaerophiles*) and design corresponding environmental culturing parameters to support or inhibit their growth. • Evaluate a disease transmission pathway using the logical sequence of Koch's Postulates to establish definitive scientific causation between a specific microbe and a clinical pathology. • Design and execute a multi-step serial dilution series to mathematically back-calculate and quantify living microbial density as Colony

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	Forming Units per milliliter (CFU/mL) from viable plate counts." ● Critique the limitations of historical microbiological frameworks when applied to modern biotechnology challenges, including unculturable pathogens, multi-agent syndemics, and rapid viral or bacterial mutations. ● Construct and interpret a mathematical bacterial growth curve, identifying and calculating cellular dynamics across the four distinct phases: *lag phase, log (exponential growth) phase, stationary phase, and death phase*.

Interdisciplinary Connections:

- **ELA NJSLS**
  - **W.WR.9–10.5.** 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.
  - **SL.UM.9–10.5.** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance findings, reasoning, and evidence and to add interest.
  - **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.
- **Math NJSLS**
  - **MP 2-** Reason abstractly and quantitatively.
  - **MP 4-**Model with mathematics.
  - **N.Q-1**-Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays

Stage 2: Assessment Evidence

Performance Task(s):	Other Evidence:
● Lab: Identification of Bacteria ● Lab: Gram Stain ● Serial Dilutions ● Lab: Aseptic Technique ● Activity 3A Lab: Making Microbiology Media and Pouring Plates ● Activity 3B Lab: Modified Kirby Bauer Test	● Serial Dilution Quiz ● Quizzes ● Test

Stage 3: Learning Plan

Learning Opportunities/Strategies:	Resources:
● Team building activities ● Cooperative learning activities ● Online learning websites ● Internet research ● Student driven activities	● Textbook: Biotechnology: A Laboratory Skills Course: J. Kirk Brown ● Gram Stain (Carolina BioKit) ● LB Agar, Ampicillin, Petri dishes, *E.coli* culture LGBT and Disabilities Resources: ● LGBTQ-Inclusive Lesson & Resources by Garden State Equality and Make it Better for Youth ● LGBTQ+ Books

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	DEI Resources: ● Learning for Justice ● GLSEN Educator Resources ● Supporting LGBTQIA Youth Resource List ● Respect Ability: Fighting Stigmas, Advancing Opportunities ● NJDOE Diversity, Equity & Inclusion Educational Resources ● Diversity Calendar

Differentiation *Please note: Teachers who have students with 504 plans that require curricular accommodations are to refer to Struggling and/or Special Needs Section for differentiation

High-Achieving Students	On Grade Level Students	Struggling Students	Special Needs/ELL
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Unit Title: Unit 4: DNA Structure and Analysis

Stage 1: Desired Results

Standards & Indicators:

NJSLS Science:

- HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells. Application: Modeling the chemical architecture of DNA (antiparallel strands, base pairing) and predicting how alterations or recombinant insertions affect downstream sequence translation.
- HS-LS3-2: Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3)

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mutations caused by environmental factors. Application: Analyzing restriction profiles, plasmid map variations, and identifying mutations/polymorphisms during forensic DNA fingerprinting or RFLP simulations.
- HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. Application: Deconstructing the steps of a recombinant cloning pipeline (restriction digest choice → gel verification → ligation strategy → map auditing) to program a host cell.

Science and Engineering Practices(SEP)
- Developing and Using Models: Use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1-1)
- Planning and Carrying Out Investigations: Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence... select appropriate tools to ensure modifications in practice are sound. (HS-LS3-2)
- Using Mathematics and Computational Thinking: Apply concepts of statistics and probability to scientific and engineering questions and problems. (HS-ETS1-2)

Disciplinary Core Ideas (DCI)
- 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.Application: Exploring the physical storage of code, thermal melting dynamics, and utilizing synthetic vectors (plasmids) containing modular genetic scripts (ori, promoters, selectable markers). (HS-LS1-1)
- LS3.B: Variation of Traits: Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.Application: Harnessing Short Tandem Repeats (STRs) and non-coding structural polymorphisms as stable, inherited biometric targets for molecular classification. (HS-LS3-2)
- ETS1.B: Developing Possible Solutions: Both physical models and computer simulations can be useful in testing the design of a particular solution... Testing a design involves looking at how well it hits prioritized criteria and constraints. (HS-ETS1-2)

Crosscutting Concepts (CCC)
- Structure and Function: The way an object is shaped or structured determines many of its properties and functions. (HS-LS1-1)
- Scale, Proportion, and Quantity: Algebraic thinking and analysis for linear and non-linear relationships in systems at different scales are critical components of science and engineering. (HS-LS3-2)
- Cause and Effect: Empirical evidence is required to differentiate between cause and correlation and make claims about specific molecular mechanisms. (HS-LS3-2)

Career Readiness, Life Literacies and Key Skills

Standard	Performance Expectations	Core Ideas
9.4.12.CT.1	Identify problem-solving strategies used in the development of an innovative product or practice (e.g., 1.1.12acc.C1b, 2.2.12.PF.3).	Collaboration with individuals with diverse experiences can aid in the problem-solving process, particularly for global issues where diverse solutions are needed.
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Central Idea/Enduring Understanding:	Essential/Guiding Question:
• **Thermodynamic and Mechanical Stability:** The antiparallel, double-helical structure of DNA relies on a delicate balance between high-energy covalent phosphodiester bonds (structural continuity) and low-energy hydrogen bonds (informational access), a physical architecture that determines how biological systems and biotechnological tools store, replicate, and manipulate genetic code. • **The Universal Molecular Toolkit:** Because genetic architecture is universally conservationist across domains of life, natural bacterial defense mechanisms—such as restriction endonucleases—can be isolated and repurposed by humans as universal precision tools to cut, alter, and join DNA from entirely different organisms. • **Biophysical Macromolecular Sorting:** Applying external electric fields to biomolecules suspended within a microscopic porous matrix (like agarose) allows scientists to exploit predictable physical properties—specifically net molecular charge, spatial geometry, and total molecular weight—to visually separate, resolve, and quantify fragments of genetic material. • **Calibration and Standard Verification:** Raw experimental data generated through physical analytical techniques (such as gel migration distance) lacks quantitative validity until it is mathematically interpolated against an empirical, known calibration standard (a molecular weight ladder) within a controlled, side-by-side system. • **Statistical Identification vs. Absolute Identity:** DNA profiling and molecular forensics do not prove identity through absolute genomic matching; instead, they rely on calculating the overlapping mathematical and statistical probabilities of highly variable, non-coding polymorphic regions across an individual's genome. • **Vector Programming and Engineering Logic:** Plasmids are predictable, circular genetic circuits that can be intentionally engineered with discrete modules (promoters, selectable markers, and multiple cloning sites) to act as biological vehicles, transforming host cells into customizable molecular factories for biomanufacturing. • **Overlapping Mathematical Diagnostics:** Complex, unseen structural networks—such as the layout of an engineered plasmid—can be precisely mapped and audited by	• How does the chemical antiparallel architecture and complementary base-pairing of DNA provide both absolute genetic stability and the capacity for dynamic replication? • In what ways do the thermodynamic properties of hydrogen bonding versus covalent phosphodiester bonds dictate how biotechnology tools (like heat or enzymes) manipulate DNA? • How does a cell's molecular machinery access tightly packed genomic structures without compromising structural integrity, and how do we replicate this *in vitro*? • How do natural bacterial defense mechanisms (restriction endonucleases) become universal tools for human genetic engineering? • What criteria must a researcher evaluate when selecting between enzymes that generate "sticky ends" versus "blunt ends" for downstream ligation into a vector? • How do we use external physical forces (electromagnetism) and molecular sieves (agarose) to make the invisible characteristics of macromolecules visible and quantifiable? • How does altering the structural density (agarose percentage) of a gel shift its resolution power, and how do scientists optimize this for varying fragment lengths? • Why must a researcher calibrate molecular weight standards (DNA ladders) alongside experimental samples to ensure data validity, and what are the consequences of failing to do so? • How can a known viral genome, like Lambda bacteriophage, serve as a precise molecular benchmark for testing enzyme activity and cutting efficiency? • When an experimental gel profile shows unexpected bands or smearing during a Lambda digest, how does a scientist systematically isolate variables to troubleshoot the protocol? • How does the spatial distance between restriction sites on a circular versus a linear DNA molecule change the mathematical logic used to predict fragment outputs? • How can a genome be >99.9% identical across all human beings, yet provide enough variable molecular footprints to identify a single individual out of billions? • What are the mathematical and statistical thresholds required to prove a DNA "match" in a

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cross-referencing the overlapping mathematical logic of multiple, distinct biochemical cutting patterns (single vs. double restriction digests).	court of law, and how do technical artifacts or sample degradation compromise that evidence? ● How do we balance the immense societal benefit of DNA profiling in solving crimes against the ethical challenges of genetic privacy and state-held bio-databases? ● How do we use the overlapping mathematical logic of single and double enzyme digests to reconstruct the physical spatial map of an unseen circular plasmid? ● How do biotechnical engineers intentionally design plasmids with specific features (like Multiple Cloning Sites, promoters, and antibiotic resistance genes) to turn cells into programmable biomanufacturing factories?
Content: ● DNA Structure and Analysis (Chapter 4) ● Molecular Biology ● DNA Structure ● Recombinant DNA Technology ● DNA Analysis Techniques ● Restriction Enzymes ● CRISPR	**Skills(Objectives):** ● Model the biochemical structure of a DNA nucleotide polymer, explicitly labeling the antiparallel orientation (5' to 3' vs. 3’ to 5'), phosphodiester backbone, and complementary purine-pyrimidine hydrogen bonding. ● Predict the stability and melting temperature of varying DNA sequences by analyzing the thermodynamic ratio of Adenine-Thymine (2 hydrogen bonds) to Guanine-Cytosine (3 hydrogen bonds) base pairs. ● Classify restriction endonucleases based on their recognition sequences and characterize their enzymatic cleavage patterns as producing either cohesive ("sticky") or blunt molecular ends. ● Design a theoretical cloning strategy to insert a target gene into a bacterial plasmid vector, selecting compatible restriction sites that ensure directional insertion and prevent vector self-ligation. ● Calculate and prepare specific percentages of agarose-buffer solutions (% w/v) to optimize gel matrix porosity for the separation of specific macromolecular weight ranges. ● Execute agarose gel casting and load micro-volumes of samples into wells using proper micropipetting ergonomics to prevent puncture or cross-contamination. ● Differentiate macromolecules during a dye electrophoresis simulation by analyzing how net molecular charge dictates migration direction and molecular weight/geometry dictates migration rate. ● Set up and execute an enzymatic restriction digest reaction of Lambda bacteriophage DNA, managing incubation micro-volumes, buffer

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	environments, and temperature constraints to achieve complete cleavage. ● Construct a standard semi-logarithmic calibration curve utilizing the migration distances of a known DNA ladder to mathematically interpolate the base-pair sizes of unknown Lambda DNA fragments. ● Diagnose and troubleshoot common gel anomalies (e.g., "smiling" bands, DNA smearing, faint bands, or incomplete digests) by systematically isolating experimental and equipment variables. ● Simulate a forensic DNA analysis profile by comparing Short Tandem Repeat (STR) or Restriction Fragment Length Polymorphism (RFLP) patterns from a mock crime scene against multiple suspect samples. ● Mathematically reconstruct the physical structure of an unknown circular plasmid by analyzing and cross-referencing fragment size data generated from single and double enzyme digests. ● Annotate a structural plasmid map, correctly locating critical engineered features including the Origin of Replication (*ori*), Multiple Cloning Site (*MCS*), promoter regions, and selectable antibiotic resistance markers.

Interdisciplinary Connections:

- **ELA NJSLS**
  - **W.WR.9–10.5.** 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.
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  - **MP 4-**Model with mathematics.
  - **N.Q-1**-Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data display

Stage 2: Assessment Evidence

Performance Task(s):	Other Evidence:
● Casting Agarose Gels ● Dye Electrophoresis ● Restriction Digestion and Analysis of Lambda DNA ● Forensic DNA Fingerprinting ● Plasmid Mapping ● Chopped! Using CRISPR/Cas9 to cut DNA Lab	● Quizzes ● Tests

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Stage 3: Learning Plan

Learning Opportunities/Strategies:

- Team building activities
- Cooperative learning activities
- Online learning websites
- Internet research
- Student driven activities

Resources:

- Textbook: Biotechnology: A Laboratory Skills Course: J. Kirk Brown
- *Lambda DNA Restriction Digestion Analysis Lab* - miniPCR bio Company
- *Principles of Gel Electrophoresis/DNA to the Races Laboratory* - Carolina Biological Supply Company
- *Chopped! Using CRISPR/Cas9 to cut DNA Lab* - miniPCR bio Company
- blueGel™ electrophoresis with built-in transilluminator - 1 per 2 students

LGBT and Disabilities Resources:

- LGBTQ-Inclusive Lesson & Resources by Garden State Equality and Make it Better for Youth
- LGBTQ+ Books

DEI Resources:

- Learning for Justice
- GLSEN Educator Resources
- Supporting LGBTQIA Youth Resource List
- Respect Ability: Fighting Stigmas, Advancing Opportunities
- NJDOE Diversity, Equity & Inclusion Educational Resources
- Diversity Calendar

Differentiation *Please note: Teachers who have students with 504 plans that require curricular accommodations are to refer to Struggling and/or Special Needs Section for differentiation

High-Achieving Students	On Grade Level Students	Struggling Students	Special Needs/ELL
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		Allow the use of technology on assignments Allow students to collaborate in small groups	ELL supports should include, but are not limited to, the following:: Extended time Provide visual aids Repeated directions Differentiate based on proficiency Provide word banks Allow for translators, dictionaries

Unit Title: Unit 5: Bacterial Transformation and Protein Purification

Stage 1: Desired Results

Standards & Indicators:

NJSLS Science:

- HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells. Application: Evaluating how modular synthetic plasmids (promoters, selectable markers) function inside a host cell to direct the translation and expression of target recombinant proteins.
- HS-LS3-2: Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. Application: Analyzing the lateral mechanisms of horizontal gene transfer (conjugation and transformation) as alternative, non-vertical pathways for driving rapid genetic variation and phenotypic changes across bacterial populations.
- HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. Application: Deconstructing an upstream industrial production bottleneck into micro-steps: establishing cell competency → executing heat shock transformation → processing cellular yields through alkaline lysis minipreps.

Science and Engineering Practices(SEP)

- **Planning and Carrying Out Investigations:** Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence... select appropriate tools to ensure modifications in practice are sound. (HS-ETS1-2)
- **Using Mathematics and Computational Thinking:** Apply concepts of statistics and probability to scientific and engineering questions and problems. (HS-ETS1-2)
- **Analyzing and Interpreting Data:** Evaluate the impact of new data on a working explanation and/or design of a proposed procedure or system. (HS-LS3-2)

Disciplinary Core Ideas (DCI)

- **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. (HS-LS3-2)
- **LS3.B: Variation of Traits:** Environmental factors also affect expression of traits... and viable mutations are inherited. (HS-LS3-2)
- **ETS1.B: Developing Possible Solutions:** Both physical models and computer simulations can be useful in testing the design of a particular solution. (HS-ETS1-2)

Crosscutting Concepts (CCC)

- **Structure and Function:** The way an object is shaped or structured determines many of its properties and functions. (HS-LS1-1)

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- **Cause and Effect:** Empirical evidence is required to differentiate between cause and correlation and make claims about specific mechanisms. (HS-LS3-2)
- **Scale, Proportion, and Quantity:** Algebraic thinking and analysis for linear and non-linear relationships in systems at different scales are critical components of science and engineering. (HS-ETS1-2)

Career Readiness, Life Literacies and Key Skills

Standard	Performance Expectations	Core Ideas
9.4.12.CT.1	Identify problem-solving strategies used in the development of an innovative product or practice (e.g., 1.1.12acc.C1b, 2.2.12.PF.3).	Collaboration with individuals with diverse experiences can aid in the problem-solving process, particularly for global issues where diverse solutions are needed.
9.4.12.TL.1	Assess digital tools based on features such as accessibility options, capacities, and utility for accomplishing a specified task (e.g., W.11-12.6.).	Digital tools differ in features, capacities, and styles. Knowledge of different digital tools is helpful in selecting the best tool for a given task.

Central Idea/Enduring Understanding:

- **The Bioreactor Optimization Challenge:** The intersection of a bacterium's exponential growth capacity with its rate of spontaneous mutation creates a continuous evolutionary optimization challenge within industrial bioreactors and healthcare environments.
- **Non-Reproductive Evolutionary Timelines:** Bacteria bypass traditional, multi-generational evolutionary timelines by executing horizontal gene transfer via conjugation, enabling rapid, non-reproductive genetic recombination across populations.
- **Exploitation of Recombinant Mechanics:** The dynamics of physical genetic transfer—including F+, F-, and high-frequency recombination (Hfr) states—form the natural biological blueprint that biotechnologists exploit to engineer synthetic plasmids and transfer desired traits into host cells.
- **Non-Vertical Evolutionary Acceleration:** Bacteria bypass traditional generational inheritance by executing horizontal gene transfer through physical contact (conjugation), enabling the rapid, lateral dissemination of complex genetic traits—such as multi-drug antibiotic resistance—across diverse microbial populations.
- **Modular Engineering of Living Factories:** Synthetic plasmids function as programmable, modular genetic circuits; by deliberately combining functional elements like replication origins, selectable markers, and targeted promoters, biotechnologists can hijack cellular machinery to mass-produce complex human therapeutics.

Essential/Guiding Question:

- Modular Engineering Constraints: In what ways do the individual structural modules of a plasmid (ori, promoter, MCS, antibiotic resistance marker) function together as a unified genetic circuit, and how do bio-engineers choose these parts to prevent metabolic exhaustion in host cells?
- The Living Factory Metaphor: How does the industrial scale-up of therapeutic proteins (like insulin or monoclonal antibodies) rely on human ability to reprogram prokaryotic machinery using synthetic plasmids?
- Overcoming Cellular Boundaries: What physical and chemical principles must a researcher exploit to force a cell's negatively charged lipid bilayer to accept a foreign, negatively charged plasmid molecule during chemical transformation?
- Yield vs. Viability Paradox: How do researchers optimize transformation efficiency, and why does an increase in the quantity of plasmid DNA introduced not always yield a linear increase in successful transformants?
- Exploiting Biochemical Vulnerabilities: How does alkaline lysis systematically exploit the structural and chemical differences between circular plasmid DNA and linear genomic DNA to selectively isolate foreign genetic loops from cellular debris?
- Quantifying the Invisible: Why is spectral absorbance at specific UV wavelengths (A_{260} vs. A_{280}) a universal metric for testing molecular purity, and how do chemical contaminants left behind from a purification process distort downstream results?

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- **Overcoming Biophysical Envelopes:** Introducing foreign genetic material into a living cell requires the artificial manipulation of its biophysical boundaries; establishing chemical competency and applying thermal or electrical disruption dynamically alters membrane permeability to allow the uptake of negatively charged DNA molecules.
- **Mathematical Validation of Molecular Efficiency:** The success of a genetic modification assay is not measured merely by phenotypic presence, but must be quantitatively validated by calculating transformation efficiency, establishing an empirical metric to optimize protocol conditions and scale-up logistics.
- **Exploiting Topology for Chemical Isolation:** Macromolecules can be selectively isolated from complex cellular matrices by exploiting differences in their physical size, geometry, and structural topology; alkaline lysis denaturation and differential precipitation allow fragile, supercoiled plasmid loops to separate cleanly from massive, tangled genomic chromosomes.
- **Spectroscopic Quality Control:** The intrinsic physical chemistry of molecular bonds—such as the unique ultraviolet light absorbance profiles of aromatic rings in nucleic acids versus amino acids—provides an unalterable chemical signature used to mathematically audit the concentration, purity, and downstream viability of engineered bioproducts.

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- In a closed system, what forces ultimately limit exponential biological expansion, and how do bioprocess engineers manipulate those limits?
- In what ways does bacterial genetic recombination reshape our understanding of heredity, evolution, and natural selection?
- How does nature's mechanism for horizontal gene transfer serve as both a biological threat (e.g., antibiotic resistance) and a primary tool for human bio-engineering?

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Content:

- Bacterial Transformation and Plasmid Purification (Chapter 5)
- Conjugation
- Plasmid structure
- Uses of plasmids in Biotechnology
- Transformation application in Biotechnology
- Purifying plasmid DNA from a culture
- DNA quantitation using a spectrophotometer

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Skills(Objectives):

- Mechanisms of Conjugation: Differentiate between the molecular mechanisms of conjugation, transformation, and transduction, explaining how conjugation specifically requires direct cell-to-cell contact via a sex pilus to transfer genetic material.
- Structural Anatomy of Plasmids: Analyze the structural anatomy of an engineered plasmid vector, identifying the functional roles of the Origin of Replication (ori), Multiple Cloning Site (MCS), promoter regions, and selectable antibiotic resistance markers.
- Industrial Utility of Vectors: Evaluate the uses of synthetic plasmids in biotechnology, detailing how they function as expression vectors for mass protein biomanufacturing (e.g., insulin production) or as cloning vectors for genomic sequencing.
- Biotechnical Applications of Transformation: Explain the commercial applications of bacterial transformation in biotechnology, specifically how

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	chemical competency ($CaCl_2$) and thermal shock allow foreign DNA to bypass the lipid bilayer of host cells. ● Executing Transformation Assays: Execute a multi-day bacterial transformation assay (e.g., pGLO or pBLU systems), calculating transformation efficiency using the mathematical ratio of total colonies grown to the mass of plasmid DNA spread. ● Chemical Lysis and Decanting: Perform an alkaline lysis miniprep protocol to isolate and purify plasmid DNA from a liquid bacterial culture, systematically isolating chromosomal DNA, proteins, and cellular debris through differential centrifugation. ● Spectrophotometric DNA Quantitation: Quantitate the concentration and purity of isolated plasmid DNA utilizing UV-visible spectrophotometry, measuring light absorbance ratios at A_{260} and A_{280} (260/280 ratio) to determine the extent of RNA or protein contamination.

Interdisciplinary Connections:

- **ELA NJSLS**
  - **W.WR.9–10.5.** 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.
  - **SL.UM.9–10.5.** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance findings, reasoning, and evidence and to add interest.
- **Math NJSLS**
  - **MP 4-**Model with mathematics.
  - **N.Q-1**-Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data display

Stage 2: Assessment Evidence

Performance Task(s):	Other Evidence:
● Control of Gene Expression in Prokaryotes POGIL ● pGLO Bacterial Transformation Lab ● Activity 5.D DNA Quantitation Part 1: Gel Quantitation ● How to use a Spectrophotometer Activity ● Application: Quantifying DNA using Gel Electrophoresis	● Classroom discussions ● Writing Tasks/Article Analysis

Stage 3: Learning Plan

Learning Opportunities/Strategies:	Resources:
● Team building activities ● Cooperative learning activities ● Online learning websites	● Textbook: Biotechnology: A Laboratory Skills Course: J. Kirk Brown

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• Internet research • Student driven activities	• *pGLO Bacterial Transformation Kit* - BioRad Company LGBT and Disabilities Resources: • LGBTQ-Inclusive Lesson & Resources by Garden State Equality and Make it Better for Youth • LGBTQ+ Books DEI Resources: • Learning for Justice • GLSEN Educator Resources • Supporting LGBTQIA Youth Resource List • Respect Ability: Fighting Stigmas, Advancing Opportunities • NJDOE Diversity, Equity & Inclusion Educational Resources • Diversity Calendar

Differentiation *Please note: Teachers who have students with 504 plans that require curricular accommodations are to refer to Struggling and/or Special Needs Section for differentiation

High-Achieving Students	On Grade Level Students	Struggling Students	Special Needs/ELL
Allow the use of technology on assignments Provide web-based projects to further expand class materials Allow students to collaborate in small groups	Provide visual aides Study guides Allow the use of technology on assignments Allow students to collaborate in small groups	Graphic Organizers Shorten assignments Grade for content not spelling and grammar Allow extra time for assignments if student goes to tutoring Provide visual aides Study guides Allow the use of technology on assignments Allow students to collaborate in small groups	Any student requiring further accommodations and/or modifications will have them individually listed in their 504 Plan or IEP. These might include, but are not limited to: breaking assignments into smaller tasks, giving directions through several channels (auditory, visual, kinesthetic, model), and/or small group instruction for reading/writing ELL supports should include, but are not limited to, the following:: Extended time Provide visual aids Repeated directions Differentiate based on proficiency Provide word banks Allow for translators, dictionaries

Biotechnology Honors

Unit Title: Unit 6: The Polymerase Chain Reaction

Stage 1: Desired Results

Standards & Indicators:

NJSLS Science:

- HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
- HS-LS3-1: Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.
- HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Science and Engineering Practices(SEP)

- **Using Mathematics and Computational Thinking:** Apply concepts of statistics and probability to scientific and engineering questions and problems. (HS-LS3-1)
- **Asking Questions and Defining Problems:** Ask questions that arise from careful analysis of a complex set of explanations, a model, or a chemical system, to determine relationships between components. (HS-LS3-1)
- **Constructing Explanations and Designing Solutions:** Select the most appropriate molecular mechanism or technique to address a real-world biomedical or agricultural diagnostic need. (HS-ETS1-2)

Disciplinary Core Ideas (DCI)

- **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. (HS-LS1-1)
- **LS3.B: Variation of Traits:** Though DNA replication is tightly regulated, errors or targeted polymorphic variations occur and can be structurally analyzed. (HS-LS1-1)
- **ETS1.B: Developing Possible Solutions:** When evaluating a design solution, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social and environmental impacts. (HS-ETS1-2)

Crosscutting Concepts (CCC)

- **Scale, Proportion, and Quantity:** Algebraic thinking and analysis for linear and non-linear relationships in systems at different scales are critical components of science and engineering. (HS-LS3-1)
- **Structure and Function:** The way an object is shaped or structured determines many of its properties and functions.(HS-LS1-1)
- **Cause and Effect:** Empirical evidence is required to differentiate between cause and correlation and make claims about specific mechanisms. (HS-ETS1-2)

Career Readiness, Life Literacies and Key Skills

Standard	Performance Expectations	Core Ideas
9.4.12.CT.1	Identify problem-solving strategies used in the development of an innovative product or practice (e.g., 1.1.12acc.C1b, 2.2.12.PF.3).	Collaboration with individuals with diverse experiences can aid in the problem-solving process, particularly for global issues where diverse solutions are needed.
9.4.12.TL.1	Assess digital tools based on features such as accessibility options, capacities, and utility for accomplishing a specified task (e.g., W.11-12.6.).	Digital tools differ in features, capacities, and styles. Knowledge of different digital tools is helpful in selecting the best tool for a given task.

Biotechnology Honors

Central Idea/Enduring Understanding:	Essential/Guiding Question:
• **Targeted In Vitro Target Amplification:** The Polymerase Chain Reaction (PCR) is a revolutionary molecular copier that exploits basic biochemical principles to amplify a specific target sequence of DNA a billion-fold *in vitro* from a trace, complex genomic sample. • **Thermodynamic Control of Molecular Kinetics:** The three stages of a PCR cycle (denaturation, annealing, and extension) rely on precise thermal manipulation to break and reform hydrogen bonds and optimize enzyme kinetics at distinct, highly controlled temperatures. • **Automated Engineering via Thermostability:** The development of automated thermal cyclers and the discovery of extremophilic, heat-stable enzymes (like *Taq* polymerase) eliminated the need for manual intervention, transforming a tedious molecular process into a highly reproducible, industrial-standard biomanufacturing and diagnostic tool. • **Evolutionary Adaptation for Synthetic Optimization:** While *in vivo* DNA replication requires a complex matrix of unstable cellular enzymes (helicase, primase, topoisomerase) to unwind and copy DNA, *in vitro* PCR strips down this biological process to its absolute essentials, replacing fragile proteins with physical forces (heat) and synthetic, targeted oligonucleotides (primers). • **The Mathematics of Spatial Specificity (Primer Design):** The fidelity and efficiency of PCR are governed by the biophysical parameters of primer design; variables such as length, GC content, melting temperature, and lack of secondary structures (like hairpins or primer-dimers) dictate the mathematical probability of non-specific binding versus absolute target accuracy. • **Modification for Quantitative and Multiplex Diagnostics:** The core biochemical framework of PCR can be adapted into specialized variations—such as Real-Time/Quantitative PCR (qPCR) to measure gene expression in real-time or Reverse Transcription PCR (RT-PCR) to analyze RNA viruses—shifting the technology from a simple qualitative tool to a highly precise analytical standard. • **The Foundational Catalyst for Modern Biotechnology:** PCR serves as the indispensable technological gatekeeper for the entire modern biotech industry; without its ability to rapidly mass-produce targeted genetic material, downstream industries like forensic	• What does the term "polymerase chain reaction" literally mean, and what is its overarching goal in a molecular biology lab? • Mathematically, how does the accumulation of DNA fragments change over a series of PCR cycles (e.g., how many copies exist after 1 cycle, 10 cycles, or 30 cycles)? • What is the difference between the "target sequence" and total genomic DNA, and why does it take three complete cycles to isolate the precise short-fragment target? • What specific roles do dNTPs (deoxynucleotide triphosphates) play during the extension phase of PCR? • Why is a specialized buffer system containing Magnesium ions (Mg_2) required for the reaction mix, and what happens to enzyme performance if the ion concentration is altered? • Why can a standard human or bacterial DNA polymerase *not* be used in a PCR assay, and what specific evolutionary adaptation makes *Taq* polymerase the industrial choice? • What physical and chemical events occur within a DNA molecule at 94℃–96℃ (Denaturation), 50℃–65℃ (Annealing), and 72℃ (Extension)? • How do the specific hydrogen bonds between purines and pyrimidines dictate the exact temperature chosen for the primer annealing step? • How does a thermal cycler achieve rapid temperature shifts, and how did its invention transform molecular research from a manual labor task to an automated workflow? • How does the method used to disrupt hydrogen bonds and separate DNA strands differ between a thermal cycler and a living cell? • How does the cell solve the "free 3'-OH group problem" using RNA primase, and how does PCR bypass this enzymatic requirement? • While cellular replication copies an organism's entire genome from end to end, what mechanisms restrict PCR to amplifying only a tiny, localized sequence? • Why are two distinct primers (forward and reverse) required to successfully amplify a double-stranded target sequence? • What is the "melting temperature" (T_m) of a primer, and why must the forward and reverse primers have closely matching T_m values? • What structural design flaws lead to the formation of "hairpins" or "primer-dimers," and

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profiling, medical molecular diagnostics (e.g., viral detection), agricultural GMO auditing, and gene-editing cloning would be physically and economically impossible.	how do these anomalies degrade total reaction efficiency? ● How does Real-Time/Quantitative PCR (qPCR) use fluorescent reporters to measure DNA mass during the active reaction, rather than waiting for the final output? ● What extra enzymatic step is required in Reverse Transcription PCR (RT-PCR) to allow the amplification of an RNA-based sample (like an influenza or coronavirus genome)? ● In what industrial scenarios would a technician choose a Multiplex PCR strategy over a standard, single-target PCR assay? ● How does the high sensitivity of PCR change the collection protocols and validation standards for trace evidence found at a forensic crime scene? ● How do agricultural diagnostic companies utilize PCR to audit livestock or verify that consumer food products are free of unapproved genetically modified organisms (GMOs)? ● Why is PCR screening considered the diagnostic "gold standard" for early pathogen detection compared to traditional antibody or culturing assays?
Content: ● The Polymerase Chain Reaction (Chapter 6) ● What is PCR? ○ Stages ○ Components ○ Thermal Cycler ○ Output ● PCR vs. DNA replication ● Types of PCR ● PCR Primer design ● Real world applications of PCR in Biotechnology	**Skills(Objectives):** ● **Mathematical Modeling of Amplification:** Calculate the theoretical yield of DNA fragments across a specified number of thermal cycles utilizing the exponential growth formula (2^n). ● **Target Sequence Kinetics:** Explain the progressive mechanics of target sequence isolation, demonstrating via diagram or text why three complete cycles are required to yield the first discrete, short-fragment target strands. ● **Thermodynamic Cycle Breakdown:** Analyze the molecular and thermodynamic events occurring during the three phases of a PCR cycle, justifying the chosen temperature parameters for denaturation 94℃–96℃ (Denaturation), 50℃–65℃ (Annealing), and 72℃ (Extension). ● **Master Mix Component Auditing:** Differentiate the functional roles of each component within a standard PCR master mix, including *Taq* polymerase, forward/reverse primers, deoxynucleotide triphosphates (dNTPs), and magnesium cofactors (Mg_2). ● **Comparative Molecular Analysis:** Contrast *in vitro* PCR with *in vivo* cellular DNA replication, explicitly comparing the mechanical methods used for strand separation, priming, elongation, and overall genomic scope.

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	• **Biophysical Primer Design Engineering:** Apply design rules to engineer a set of forward and reverse PCR primers for a target gene, optimizing variables for length, GC content, melting temperature (T_m), and the prevention of secondary structures like hairpins or primer-dimers. • **Differentiating Diagnostic Modalities:** Distinguish between standard qualitative PCR, quantitative real-time PCR (qPCR), and reverse transcription PCR (RT-PCR) based on their enzymatic mechanisms, starting templates (DNA vs. RNA), and analytical readouts. • **Real-World Implementation and Critique:** Evaluate the implementation of PCR assays across the fields of forensics (STR preparation), molecular medicine (viral load monitoring), and agriculture (GMO validation), assessing how technical artifacts or contamination alter assay validity.

Interdisciplinary Connections:

- **ELA NJSLS**
  - **W.WR.9–10.5.** 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.
  - **SL.UM.9–10.5.** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance findings, reasoning, and evidence and to add interest.
- **Math NJSLS**
  - **MP 4-**Model with mathematics.
  - **N.Q-1**-Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data display

Stage 2: Assessment Evidence

Performance Task(s):	Other Evidence:
• DNA Profiling Gizmos • PCR Virtual Lab • Sleep Lab: Lark or Owl? • Identification of Foodstuffs from Genetically Modified Organism Lab	• Classroom discussions • Writing Tasks/Article Analysis • Quizzes • Tests

Stage 3: Learning Plan

Learning Opportunities/Strategies:	Resources:
• Team building activities • Cooperative learning activities • Online learning websites • Internet research • Student driven activities	• Textbook: Biotechnology: A Laboratory Skills Course: J. Kirk Brown • *Sleep Lab: Lark or Owl?* - miniPCR bio Company • *Identification of Foodstuffs from Genetically Modified Organisms* - Carolina Biological Supply Company

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	• *Gizmos Interactive Simulations & Labs* - ExploreLearning Company • *PCR Virtual Lab* - Learn.Genetics University of Utah LGBT and Disabilities Resources: • LGBTQ-Inclusive Lesson & Resources by Garden State Equality and Make it Better for Youth • LGBTQ+ Books DEI Resources: • Learning for Justice • GLSEN Educator Resources • Supporting LGBTQIA Youth Resource List • Respect Ability: Fighting Stigmas, Advancing Opportunities • NJDOE Diversity, Equity & Inclusion Educational Resources • Diversity Calendar

Differentiation *Please note: Teachers who have students with 504 plans that require curricular accommodations are to refer to Struggling and/or Special Needs Section for differentiation

High-Achieving Students	On Grade Level Students	Struggling Students	Special Needs/ELL
Allow the use of technology on assignments Provide web-based projects to further expand class materials Allow students to collaborate in small groups	Provide visual aides Study guides Allow the use of technology on assignments Allow students to collaborate in small groups	Graphic Organizers Shorten assignments Grade for content not spelling and grammar Allow extra time for assignments if student goes to tutoring Provide visual aides Study guides Allow the use of technology on assignments Allow students to collaborate in small groups	Any student requiring further accommodations and/or modifications will have them individually listed in their 504 Plan or IEP. These might include, but are not limited to: breaking assignments into smaller tasks, giving directions through several channels (auditory, visual, kinesthetic, model), and/or small group instruction for reading/writing ELL supports should include, but are not limited to, the following:: Extended time Provide visual aids Repeated directions Differentiate based on proficiency Provide word banks Allow for translators, dictionaries

Biotechnology Honors

Unit Title: Unit 7: Protein Structure and Analysis

Stage 1: Desired Results

Standards & Indicators:

NJSLS Science:

- HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
- HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
- HS-ETS1-2**:** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Science and Engineering Practices(SEP)

- **Developing and Using Models:** Use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-LS1-2)
- **Planning and Carrying Out Investigations:** Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence. (HS-LS1-1)
- **Using Mathematics and Computational Thinking:** Apply concepts of statistics and probability to scientific and engineering questions and problems. (HS-ETS1-2)

Disciplinary Core Ideas (DCI)

- **LS1.A: Structure and Function:** Systems of specialized cells within organisms help them perform the essential functions of life... Any one system is made up of numerous parts and is itself a component of the next level. (HS-LS1-2)
- **LS3.B: Variation of Traits:** Changes in the genetic sequence (mutations) can lead to changes in the structure of inherited proteins, which can modify cell function. (HS-LS1-1)
- **ETS1.C: Optimizing the Design Solution:** Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the choices of materials may be needed. (HS-ETS1-2)

Crosscutting Concepts (CCC)

- **Structure and Function:** The way an object is shaped or structured determines many of its properties and functions. (HS-LS1-1)
- **Scale, Proportion, and Quantity:** Algebraic thinking and analysis for linear and non-linear relationships in systems at different scales are critical components of science and engineering. (HS-ETS1-2)
- **Systems and System Models:** Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the number of assumptions made. (HS-ETS1-2)

Career Readiness, Life Literacies and Key Skills

Standard	Performance Expectations	Core Ideas
9.4.12.CT.1	Identify problem-solving strategies used in the development of an innovative product or practice (e.g., 1.1.12acc.C1b, 2.2.12.PF.3).	Collaboration with individuals with diverse experiences can aid in the problem-solving process, particularly for global issues where diverse solutions are needed.
9.4.12.TL.1	Assess digital tools based on features such as accessibility options, capacities, and utility for accomplishing a specified task (e.g., W.11-12.6.).	Digital tools differ in features, capacities, and styles. Knowledge of different digital tools is helpful in selecting the best tool for a given task.

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Central Idea/Enduring Understanding:	Essential/Guiding Question:
• **The Sequence-to-Shape Paradigm:** The transition from linear genetic information to active cellular function relies on a strict folding hierarchy, where the precise chemical sequence of amino acids (**primary structure**) dictates a highly predictable, thermodynamically driven spatial folding cascade (**secondary, tertiary, and quaternary structures**) that ultimately governs all biological activity. • **Charge-Masking for Mass Resolution:** Because native proteins possess highly diverse three-dimensional geometries and varied net charges, analytical separation via **SDS-PAGE** requires complete chemical denaturation and a uniform negative charge coating to isolate and resolve protein fragments strictly by their molecular weight. • **Topographical Matrix Separation:** In contrast to denaturing techniques, **Size Exclusion Chromatography (SEC)** exploits the physical porosity of a stationary matrix to isolate native, fully functional proteins by mass, utilizing a paradoxical pathing mechanism where larger molecules bypass internal bead pathways to elute first. • **Spectroscopic and Colorimetric Metrology:** Quantifying sub-microscopic protein concentrations requires exploiting the unique chemical reactivity of peptide bonds or the light-absorbance properties of aromatic side chains, converting raw molecular behavior into standardized, actionable concentration data via spectrophotometry.	• What are the specific molecular steps involved in the transition from a linear mRNA sequence to a functional, folded polypeptide chain? • How do the unique chemical properties of amino acid R-groups (hydrophobic, hydrophilic, charged, polar) determine the folding path of a tertiary protein structure? • What types of chemical bonds stabilize secondary structures (α-helices and β-pleated sheets) compared to those that stabilize tertiary and quaternary structures? • What are the immediate biological and structural consequences when a single amino acid is substituted in a protein's primary sequence? • Why are proteins considered the actual "workhorses" of the biotechnology industry, while DNA is considered the "instruction manual"? • Why can a researcher not rely solely on visual inspection to confirm the presence of a target protein in a raw cellular lysate? • How does a colorimetric assay (such as a Bradford or BCA assay) translate the chemical presence of protein peptide bonds into a visible color change? • How do you construct and use a standard BSA (Bovine Serum Albumin) calibration curve to mathematically calculate the unknown concentration of an isolated protein sample? • Why can native proteins not be separated strictly by molecular weight using standard agarose gel electrophoresis? • What specific roles do SDS (Sodium Dodecyl Sulfate), DTT (Dithiothreitol) or β-mercaptoethanol, and heat play during sample preparation for SDS-PAGE? • How does the chemical structure of a polyacrylamide gel matrix differ from an agarose gel matrix, and why is polyacrylamide preferred for resolving proteins? • Paradoxically, why do larger proteins move through a size exclusion chromatography column faster than smaller proteins? • What is the physical composition of the stationary phase (beads) in an SEC column, and how does it create a molecular sieve?
Content:	**Skills(Objectives):**
• Protein Structure & Analysis (Chapter 7) • Protein Synthesis • Protein Structure • Proteins in Biotechnology	• Trace the molecular pathway of protein synthesis, mapping how ribosomal translation converts a linear mRNA script into a specific primary sequence of amino acids.

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• Methods of Protein Analysis
  ○ Protein Quantitation
  ○ Protein Electrophoresis (SDS-PAGE)
  ○ Size Exclusion Chromatography (SEC)
	• Model the four structural tiers of protein folding (primary, secondary, tertiary, and quaternary), identifying the specific chemical interactions (hydrogen bonds, disulfide bridges, hydrophobic interactions, and ionic bonds) stabilizing each level.
	• Predict the structural and functional consequences of specific genetic mutations by analyzing how an altered amino acid R-group changes the downstream folding thermodynamics of a protein.
	• Execute a colorimetric protein assay (e.g., Bradford), explaining the chemical mechanism by which a dye interacts with peptide backbones or aromatic side chains to induce a spectral shift.
	• Construct a standard linear calibration curve using known concentrations of Bovine Serum Albumin (BSA) and employ Beer-Lambert law principles to interpolate the concentration of an unknown protein extract.
	• Justify the chemical necessity of sample preparation parameters in SDS-PAGE, evaluating how SDS, reducing agents (DTT/β-ME), and thermal energy denature tertiary structures and impart a uniform mass-to-charge ratio.
	• Prepare and load a polyacrylamide vertical gel matrix, analyzing how its structural porosity resolves low-molecular-weight proteins at a higher resolution than horizontal agarose matrices.
	• Execute native protein isolation utilizing Size Exclusion Chromatography, analyzing how the physical porosity of the stationary matrix sieve allows larger molecules to elute ahead of smaller fragments.

Interdisciplinary Connections:

- **ELA NJSLS**
  - **W.WR.9–10.5.** 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.
  - **SL.UM.9–10.5.** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance findings, reasoning, and evidence and to add interest.
- **Math NJSLS**
  - **MP 4-**Model with mathematics.
  - **N.Q-1**-Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data display

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Stage 2: Assessment Evidence

Performance Task(s):

- BioBits: Protein Structure and Function Activity
- Got Protein? Protein Quantitation Lab (Bradford Assay)
- Size Exclusion Chromatography Lab
- pGLO SDS PAGE Extension Lab
- BioFuels Enzyme Lab

Other Evidence:

- Classroom discussions
- Writing Tasks/Article Analysis
- Quizzes
- Test

Stage 3: Learning Plan

Learning Opportunities/Strategies:

- Team building activities
- Cooperative learning activities
- Online learning websites
- Internet research
- Student driven activities

Resources:

- Textbook: Biotechnology: A Laboratory Skills Course: J. Kirk Brown
- *BioBits: Protein Structure and Function* - miniPCR bio Company
- *Got Protein?* - BioRad Company
- *pGLO SDS-PAGE Kit* - BioRad Company
- Mini-PROTEAN® Tetra Vertical Electrophoresis System - BioRad Company
- *Size Exclusion Chromatography* - BioRad Company
- *BioFuels Enzyme Kit* - BioRad Company

LGBT and Disabilities Resources:

- LGBTQ-Inclusive Lesson & Resources by Garden State Equality and Make it Better for Youth
- LGBTQ+ Books

DEI Resources:

- Learning for Justice
- GLSEN Educator Resources
- Supporting LGBTQIA Youth Resource List
- Respect Ability: Fighting Stigmas, Advancing Opportunities
- NJDOE Diversity, Equity & Inclusion Educational Resources
- Diversity Calendar

Differentiation *Please note: Teachers who have students with 504 plans that require curricular accommodations are to refer to Struggling and/or Special Needs Section for differentiation

High-Achieving Students	On Grade Level Students	Struggling Students	Special Needs/ELL
Allow the use of technology on assignments Provide web-based projects to further expand class materials Allow students to collaborate in small groups	Provide visual aides Study guides Allow the use of technology on assignments Allow students to collaborate in small groups	Graphic Organizers Shorten assignments Grade for content not spelling and grammar Allow extra time for assignments if student goes to tutoring	Any student requiring further accommodations and/or modifications will have them individually listed in their 504 Plan or IEP. These might include, but are not limited to: breaking assignments into smaller tasks, giving directions through several channels (auditory, visual, kinesthetic, model), and/or

		Provide visual aides Study guides Allow the use of technology on assignments Allow students to collaborate in small groups	small group instruction for reading/writing ELL supports should include, but are not limited to, the following:: Extended time Provide visual aids Repeated directions Differentiate based on proficiency Provide word banks Allow for translators, dictionaries

Unit Title: Unit 8: Bioethics

Stage 1: Desired Results

Standards & Indicators:

NJSLS Science:

- HS-LS3-2: Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.
- HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as social, cultural, and environmental impacts.

Science and Engineering Practices(SEP)

- **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. (HS-LS3-2)
- **Asking Questions and Defining Problems** Ask questions that arise from examining biotechnology models, theories, or medical case studies to clarify ethical boundaries and determine the validity of a socio-scientific claim. (HS-ETS1-3)

Disciplinary Core Ideas (DCI)

- **LS3.B: Variation of Traits** Environmental factors and technological interventions (such as CRISPR, gene therapy, and cloning) can alter gene expression and genetic traits, demanding structural evaluation of their systemic risks.
- **ETS1.B: Developing Possible Solutions** Evaluating bioengineering or medical solutions involves systematically evaluating criteria and trade-offs, strictly accounting for social, cultural, ethical, and legal constraints.

Crosscutting Concepts (CCC)

- **Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific biological consequences when manipulating living systems.
- **Stability and Change** Much of science deals with constructing explanations of how living systems change and how they remain stable when technological interventions are introduced.

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Career Readiness, Life Literacies and Key Skills		
Standard	**Performance Expectations**	**Core Ideas**
9.4.12.CT.1	Identify problem-solving strategies used in the development of an innovative product or practice (e.g., 1.1.12acc.C1b, 2.2.12.PF.3).	Collaboration with individuals with diverse experiences can aid in the problem-solving process, particularly for global issues where diverse solutions are needed.
9.4.12.TL.1	Assess digital tools based on features such as accessibility options, capacities, and utility for accomplishing a specified task (e.g., W.11-12.6.).	Digital tools differ in features, capacities, and styles. Knowledge of different digital tools is helpful in selecting the best tool for a given task.

Central Idea/Enduring Understanding:	**Essential/Guiding Question:**
● Genetic Engineering in the creation of Genetically Modified Organisms that have desired features, increased nutrition, or herbicide/insecticide resistance, has revolutionized agriculture as a whole. ● Transgenic animals can be created to mature quicker, grow larger, reproduce faster, or resist pests and illnesses, all which increase productivity. ● Transgenic bacteria have been created to naturally synthesize human hormones, such as insulin or pharmaceuticals. This allows drug companies to produce human treatments safer, cheaper, and with less side effects to patients that need it. ● Genetic engineering and Genomics are transforming medical diagnoses by detecting diseases quicker and earlier. ● Genetic engineering and Genomes have the potential to target medical therapies to one individual creating a new industry of personalized medicine. ● DNA fingerprinting can help identify individuals, useful for the forensic community. ● Genetic engineering and forensic testing has created a wave of ethical dilemmas that are still being worked through. USA and EU have different approaches to handle the ongoing matter.	● How do we determine whether genetically modified plants are safe for human consumption? ● What experimental evidence confirms that we have introduced a useful gene into a transgenic organism and that it performs as we anticipate? ● How do we certify that vaccines produced in plants are effective? ● How do we know from DNA analysis that a human fetus has sickle cell anemia? ● How do we know in DNA microarray analysis that specific genes are being expressed in a specific tissue? ● How do we know whether a forensic DNA profile comes from only one individual?
Content:	**Skills(Objectives):**
● Watch Harvest of Fear and discuss the impacts of GMO in the US vs. EU. ● Watch How to Survive a Plague and discuss the ethics of the FDA process for treatments of lethal diseases. ● Complete a research project on a current event in Bioethics and create a brochure describing your opinion on the issue.	● Apply the information from previous chapters to explain genetic modifications and testing in society. ● Critique the usefulness of these advances in science to society. ● Compare and contrast the latest advances to the older methods on a monetary basis, time constraint, and natural resources limitation.

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• Conduct a formal classroom debate on GMO organisms as problem solving techniques in ecology. • Show the class Mrs. Chazan's personal genome data (personalgenomes.org, Coriell Personalized Medicine Collaborative®) and discuss the benefits and deterrents of knowing personal genetic information.	• Determine if a commonly eaten food has a GMO. • Devise ways that these advances could be harmful in the future. • Evaluate the benefits with the negative side effects to reach a final conclusion. Examples include: Would you eat a GMO? Would you have your genome stored for future genetic testing/treatments? Would you take a medication or treatment that was "fast tracked" through the FDA approval process?

Interdisciplinary Connections:

- **ELA NJSLS**
  - **W.WR.9–10.5.** 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.
  - **SL.UM.9–10.5.** Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance findings, reasoning, and evidence and to add interest.
- **Math NJSLS**
  - **MP 4-**Model with mathematics.
  - **N.Q-1**-Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data display

Stage 2: Assessment Evidence

Performance Task(s):	**Other Evidence:**
• Research presentation on a current event in Bioethics • Debate on a current event in Bioethics • Complete the Identification of Foodstuffs from Genetically Modified Organisms Laboratory.	• Classroom discussions • Writing Tasks/Article Analysis

Stage 3: Learning Plan

Learning Opportunities/Strategies:

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Resources:

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- 60 Minutes news videos (YouTube), NYTimes, Science, Nature, Philadelphia Inquirer
- *How to Survive a Plague*. Directed by David France, Public Square Films, 2012. *Amazon Prime Video*, amazon.com.
- "Harvest of Fear." *Frontline* and *NOVA*, written, produced, and directed by Jon Palfreman, PBS, 24 Apr. 2001, www.pbs.org/wgbh/harvest/.

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Pacing Guide

Course Name	Textbook: Biotechnology: A Laboratory Skills Course	Content Standards
UNIT 1 & 2 The Biotechnology Industry & Laboratory Skills (17 days)	**CHAPTER 1 & 2**	HS-ETS1-1 HS-ETS1-2
MP 1 or 3		
UNIT 3 Microbiology and Cell Culture (12 Days)	**CHAPTER 3**	HS-LS1-1 HS-LS1-2
MP 1 or 3		
UNIT 4 DNA Structure and Analysis (13 Days)	**CHAPTER 4**	HS-LS1-1 HS-LS3-2 HS-ETS1-2
MP 1 or 3		
UNIT 5 Bacterial Transformation and Plasmid Purification (13 days)	**CHAPTER 5**	HS-LS1-1 HS-LS3-1 HS-ETS1-2
MP 2 or 4		
UNIT 6 The Polymerase Chain Reaction (13 Days)	**CHAPTER 6**	HS-LS1-1 HS-LS3-1 HS-ETS1-2
MP 2 or 4		
UNIT 7 Protein Structure and Analysis (12 Days)	**CHAPTER 7**	HS-LS1-1 HS-LS1-2 HS-ETS1-2
MP 2 or 4		
UNIT 8 Bioethics (10 Days)	**Outside sources, current events**	HS-LS3-2 HS-ETS1-3