Wall Township Public Schools	Board Approval Date:
Course Title: Honors Microbiology	
Course Description: Honors Microbiology is a full-year, laboratory-intensive science elective for students in grades 10–12 who have successfully completed Biology. Students explore microscopic organisms such as bacteria, viruses, fungi, and protists and the role those organisms play in human health, food and water safety, agriculture, industry, and more. The course is heavy on laboratory work and structure: students will master aseptic technique, culture and stain microorganisms, control and measure microbial growth, run biochemical tests, and identify an unknown organism, working exclusively with Biosafety Level 1 (BSL-1) organisms under American Society for Microbiology safety guidelines. Real-world scenarios and case studies are embedded throughout the course.	

New Jersey Student Learning Standards - Science (Click here to skip below to a description about the Standards)

Course Sequence & Pacing

Unit Title	Estimated Number of Instructional Periods
Unit 1: Foundations of Microbiology: Biosafety, Sterile Technique, and Careers in the Field	12
Unit 2: Microbial Life	44

Midterm Performance Assessment	7
Unit 3: The Microbial World	17
Unit 4: Microbes and Man	28
Unit 5: Microbes and the Environment	15
Final Performance Assessment	7

Unit 1

Desired Results

Unit 1 Title: Foundations of Microbiology: Biosafety, Sterile Technique, and Careers in the Field

Unit Summary:

Students will learn exactly what a new laboratory hire does as they practice the lab Biosafety conduct that governs subsequent laboratory periods (handwashing on entry and exit, bench disinfection before and after work, correct PPE use, laboratory safety agreement, etc. They learn to operate the compound light microscope, prepare wet mounts, and estimate specimen size from a measured field of view. Students will also be introduced to the professional landscape of the field: clinical and medical laboratory science, public health epidemiology, food safety, water and environmental quality, pharmaceutical quality control, and agricultural and industrial microbiology. Students research the credentials, coursework, and transferable skills each pathway requires. The unit closes with the history that produced the field (the displacement of spontaneous generation by biogenesis and the germ theory) so that students understand microbiology as a body of contested, evidence-driven claims rather than a set of settled facts.

Learning Standards

NJSLS:

- HS-LS4-1. Communicate scientific information that common ancestry and biological evolution are supported by

multiple lines of empirical evidence.

- 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 possible social, cultural, and environmental impacts. expectation directly related to climate, climate change, or the effects of a changing climate on environmental systems.

Interdisciplinary Connections

Career Readiness, Life Literacies, & Key Skills *(CLKS)*:

- 9.2.12.CAP.4: Evaluate different careers and develop various plans (e.g., costs of public, private, training schools) and timetables for achieving them, including educational/training requirements, costs, loans, and debt repayment.
- 9.2.12.CAP.6: Identify transferable skills in career choices and design alternative career plans based on those skills.
- 9.4.12.CI.2: Identify career pathways that highlight personal talents, skills, and abilities (e.g., 1.4.12prof.CR2b, 2.2.12.LF.8).

Computer Science & Design Thinking (*CS & DT***):**

- 8.2.12.ITH.1: Analyze a product to determine the impact that economic, political, social, and/or cultural factors have had on its design, including its design constraints. (Applied to the design of the autoclave and the biological safety cabinet: students trace how disease outbreaks, regulatory requirements, and cost constraints shaped the engineering of sterilization and containment equipment.)

Interdisciplinary Connections:

- ELA — RST.11-12.9: Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (Applied to the careers jigsaw, in which students reconcile occupational data from the Bureau of Labor Statistics, O*NET, ASM career profiles, and a practitioner interview.)

Learning Targets

Unit Essential Questions:	**Unit Enduring Understandings:**
• Why does working safely with microorganisms require a different set of habits than working with chemicals, plants, or animals? • How do we know microorganisms exist, and that they arise from other microorganisms rather than from nonliving matter? • What does the resolving power of an instrument determine about what a scientist is entitled to claim? • What work do microbiologists actually do, and what preparation does each pathway require? • Why is a laboratory protocol evaluated as an engineering solution rather than simply as a list of rules?	• Biosafety practice is a designed system with criteria and constraints; a protocol is judged by whether it protects the worker and the environment at acceptable cost and reliability, not by how cautious it feels. • Microorganisms are ubiquitous, so a culture that grows means nothing unless contamination has been excluded. Sterile technique is what makes microbiological evidence trustworthy. • The germ theory displaced spontaneous generation because controlled experiments produced evidence the competing explanation could not accommodate. • Instruments constrain claims: what cannot be resolved cannot be reported, and magnification without resolution adds no information. • All cells share a common ancestry; the prokaryote–eukaryote distinction and the three-domain system rest on converging lines of structural and molecular evidence. • Microbiology careers span clinical, public health, environmental, industrial, and research settings and share a common core of transferable technical and analytical skills

Vocabulary:

- microbiology, microorganism, microbe, Biosafety Level 1 (BSL-1), biosafety, aseptic technique, sterilization,

disinfection, antisepsis, autoclave, sterilization indicator, personal protective equipment (PPE), aerosol, biohazard, biohazardous waste, contamination, ubiquitous, pure culture, resolution, resolving power, magnification, total magnification, objective, ocular, parfocal, working distance, field of view, wet mount, micrometer (µm), nanometer (nm), prokaryote, eukaryote, domain, Bacteria, Archaea, Eukarya, spontaneous generation, abiogenesis, biogenesis, germ theory of disease, control, medical laboratory scientist, clinical microbiologist, epidemiologist, quality control (QC), bioprocess.

Students will be able to:

- Explain the criteria that define Biosafety Level 1 and justify why each organism used in this course meets them.
- Demonstrate compliant laboratory conduct: handwashing on entry and exit, bench disinfection before and after work, correct PPE use, aerosol minimization, and segregation of biohazardous waste.
- Operate the countertop autoclave and verify a completed cycle using autoclave tape or a sterilization indicator.
- Distinguish sterilization, disinfection, and antisepsis, and select the appropriate process for a given item or surface.
- Evaluate a written laboratory protocol against prioritized criteria (worker safety, environmental release, reliability, cost, time) and recommend a revision.
- Carry, focus, and store a compound light microscope correctly, and calculate total magnification for each objective.
- Prepare a wet mount and locate a specimen using the low-to-high-power sequence.
- Estimate the diameter of a microscopic specimen in micrometers using a measured field of view.
- Compare prokaryotic and eukaryotic cell plans and cite the lines of evidence used to place organisms in the three domains.
- Analyze the experimental designs of Redi, Needham, Spallanzani, and Pasteur and explain what each controlled and what each failed to control.
- Describe the responsibilities, work settings, credentials, and earnings range of at least five microbiology career pathways.
- Identify transferable skills shared across microbiology careers and relate them to specific skills practiced in this course.

- Select and justify a professional role to assume during the midterm and final performance assessments.

Learning Activities & Differentiation: *(Amistad & Holocaust, Asian American & Pacific Islanders, Climate Change, LGBTQ and People with Disabilities, Diversity, Equity & Inclusion [DEI])*

- Safety contract negotiation: students receive the ASM-adapted rule list with all rationales removed and must supply the reason for each rule before signing. Groups compare answers and the class drafts the posted laboratory norms. The provision for immunocompromised students and students who are or may become pregnant is discussed openly as routine professional practice rather than as an exception, modeling how workplaces accommodate health status without stigma (DEI; People with Disabilities).
- Autoclave and sterilization-indicator demonstration followed by a "did it work?" evidence check: students examine three cycle records with indicator tape and decide which loads may be released and which must be re-run.
- Protocol engineering critique: students compare the college-level pipetting protocol from a university microbiology manual against the BSL-1 high-school protocol for the same transfer and argue which constraints drove each design difference (HS-ETS1-3; 8.2.12.ITH.1).
- Ubiquity pre-lab: students predict which of ten classroom and building surfaces will yield the heaviest microbial growth, then design the sampling plan they will execute in Unit 2. Establishes the need for sterile technique before a single plate is opened.
- Microscope skill stations with an instructor check-off card; students who demonstrate mastery are certified as station coaches and pair with peers who have not yet passed.
- Field-of-view measurement: students measure field diameter at each objective with a clear plastic rule, compute µm per field, and build a laminated reference card they keep for the year. This card replaces the ocular-micrometer procedure in Investigation 2 and is used in every later sizing estimate.
- Spontaneous generation claim–evidence sort: students receive stripped data and apparatus diagrams from Redi, Needham, Spallanzani, and Pasteur, match evidence to claim, and identify the uncontrolled variable each critic exploited.
- Careers jigsaw: expert groups research one pathway using O*NET OnLine, the BLS Occupational Outlook Handbook, and ASM career resources, then teach the class. Each group reports education required, typical employers, day-to-day tasks, credentialing examinations, salary range, and named New Jersey–area employers. Profiles deliberately include microbiologists from a range of backgrounds and scientists working with disabilities in laboratory settings, and note historical cases in which researchers' contributions went uncredited (DEI; People with Disabilities).
- Guest speaker or recorded interview with a working microbiologist from a hospital laboratory, county health department, water utility, or food manufacturer, with student-generated interview questions submitted in advance (9.2.12.CAP.6).
- Role selection memo: each student writes a short statement naming the professional role they will hold for the midterm and final performance tasks and what a person in that role is accountable for.

- Differentiation: annotated pictorial safety rule list for ELLs and students with IEPs; microscope station procedures also provided as short captioned videos students may replay; careers research source sets offered at two reading levels; gifted extension comparing BSL-1 through BSL-4 containment requirements.

Assessment Evidence

Formative Assessments:

- Safety rule rationale worksheet, scored for completeness; a passing score is required before any student handles live culture.
- Microscope skills check-off, instructor-observed, pass/retry with unlimited attempts.
- Total magnification and field-of-view calculation exit ticket (three problems).
- Prokaryote–eukaryote comparison organizer with a required evidence column citing the observation that supports each distinction.
- Spontaneous generation claim–evidence card sort, photographed and reviewed for accuracy of the “uncontrolled variable” column.
- Careers jigsaw expert-group notes and instructor observation of peer teaching.
- Sterilization vs. disinfection quick-sort: six items, students place each and justify in one sentence.

Summative Assessments:

- Laboratory Safety and Sterile Technique Practical: student demonstrates handwashing, bench disinfection, PPE donning and removal, waste segregation, and autoclave loading against a scored checklist. The written portion requires selecting sterilization or disinfection for six scenarios with written justification, and one short protocol-critique item.
- Microscopy Skills Quiz: parts and function, care and handling, total magnification computation, and a specimen-size estimation problem using the student's own field-of-view reference card.
- Careers in Microbiology profile and role-selection memo: one-page profile of a chosen pathway scored with a rubric for accuracy of credentialing and earnings information, quality and citation of sources, and clarity of the transferable-skills argument.

Common Benchmark Assessments:

- Course Diagnostic Pre-Assessment, administered during the first week: a shortened performance task using the identical seven-trait rubric applied to the midterm and final, so that growth is measured against constant criteria across the year.
- Laboratory Safety Certification: Safety checklist, students may not handle live cultures until they are certified and pass this.

Alternative Assessments:

- Illustrated safety poster or 60-second station-safety video with narration naming the hazard controlled and the consequence of skipping the step.
- Oral practical: student narrates each step of sterile bench setup while performing it, substituted for the written scenario section.
- Career pathway infographic, slide deck, or recorded informational interview submitted in place of the written profile.
- Modeled microscope demonstration to a small group, substituted for the written portion of the microscopy quiz.

Core Instructional & Supplemental Materials

- Van Hoeck, Kathy. Microbiology—Laboratory Activities. Flinn Scientific. Investigation 1: Use of the Light Microscope; Investigation 2: Microscopic Measurement (adapted — field-of-view estimation substituted for ocular micrometer).
- American Society for Microbiology, Guidelines for Biosafety in Teaching Laboratories — BSL-1 rules and student safety agreement.
- 2016 Microbiology Laboratory Manual, Activity #1: Lab Safety, Aseptic Technique, and Inoculation (college source, adapted to high school; micropipette and culture-collection sections omitted).
- Compound light microscopes; glass slides and cover slips; lens paper and Kimwipes; prepared demonstration slides; clear plastic rules for field-of-view measurement; digital microscope camera (optional, for shared projection of student fields).

- Saniclave countertop autoclave; autoclave tape and sterilization indicator labels; germicidal lamp; infrared sterilizer (eliminates open-flame Bunsen burner use).
- Safety goggles; non-latex gloves; lab coats and command-hook storage; disinfectant spray; biohazard disposal bags; wash bottles.
- U.S. Bureau of Labor Statistics, Occupational Outlook Handbook (Microbiologists; Clinical Laboratory Technologists and Technicians); O*NET OnLine; ASM Careers in Microbiology; New Jersey Department of Health career pages.
- Flinn Scientific Safety Data Sheets for all stains and reagents used in the course.

Accommodations and Modifications: Students with Disabilities, English Language Learners, Students at Risk of Failure, Students with 504s, Gifted & Talented Students

Specific Strategies and Practices that Support Students with Disabilities: Students receiving Special Education programming have specific goals and objectives, as well as accommodations and modifications outlined within their Individualized Education Plans (IEP) due to an identified disability and/or diagnosis. In addition to exposure to the general education curriculum, the instruction is differentiated based upon the student's needs. The IEP acts as a supplemental curriculum guide inclusive of instructional strategies that support each learner.

Unit-specific strategies: Safety rules issued as a one-page pictorial checklist taped inside the student's assigned lab drawer. The microscope carry-focus-store sequence is broken into a four-step card with a physical model demonstration before any independent attempt. Extended time and unlimited re-attempts on the safety practical with the checklist visible. Preferential seating at the bench nearest the sink and eyewash station. A designated peer safety partner assigned for the first three laboratory periods, with the partnership named explicitly so responsibility is mutual rather than one-directional.

Specific Strategies and Practices that Support English Language Learners: English language learner (ELL) is a national-origin-minority student who is limited-English-proficient. This term is often preferred over limited-English-proficient (LEP) as it highlights accomplishments rather than deficits.

Unit-specific strategies: Bilingual glossary of the twelve safety verbs (wash, disinfect, discard, label, report, sterilize, dispose, cover, secure, contain, notify, verify) built before the safety agreement is read. Permanent room signage labeled in the student's home language alongside English. The safety agreement read aloud and paraphrased sentence by sentence, with student restatement checked. Microscope station videos captioned. Students permitted to demonstrate procedures rather than describe them during the practical assessment.

Students at Risk of Failure — unit-specific strategies: Safety certification may be retaken as many times as needed with no grade penalty, so that laboratory access is never gated behind a single graded attempt. Careers research narrowed to two pathways with a curated source set provided. A brief check-in at the start of each laboratory period to confirm the student can state the day's goal. Missing-work recovery scheduled inside the first two weeks specifically to prevent early accumulation in a new elective.

Students with 504 Plans: Teachers are responsible for implementing designated services and strategies identified on a student's 504 Plan. 504 plans are formal plans that schools develop to give kids the support they need and cover any condition that limits daily activities in a major way. Students' accommodations are outlined in their individual 504 plan.

Unit-specific strategies: Bench height adjusted or a lab stool provided for standing-tolerance limitations. Goggles compatible with prescription eyewear stocked and fitted. Nitrile gloves confirmed for all students; the room's entire glove supply verified latex-free before the first laboratory. Alternative hand-hygiene products available for students with documented dermatologic conditions. Scheduled breaks documented during the extended practical assessment.

Specific Strategies and Practices that Support Gifted & Talented Students: It is critical that all teachers are able to recognize a high-ability student who may need more depth and complexity in instruction.

Unit-specific strategies: Students compare BSL-1 through BSL-4 containment criteria and write a memo explaining why a named pathogen is excluded from a secondary school laboratory and what facility features would be required to work with it. Certified station coaches for the microscopy check-off. Independent research into the full credentialing pathway (ASCP Medical Laboratory Scientist or NRCM Registered Microbiologist) including examination content outlines, presented to the class.

Unit 2

Desired Results

Unit 2 Title: Microbial Life

Unit Summary: This is the technical core of the course. Students build the working repertoire of a bench microbiologist: aseptic transfer, broth and agar slant culture, streak plating for isolation, simple and negative staining, the Gram stain, and systematic description of colony and cell morphology. They then investigate what controls microbial growth (chemical antiseptics and disinfectants, ultraviolet radiation, and antibiotics) and what microbes require in order to grow (temperature, oxygen availability, pH, osmotic pressure, and nutrients). They distinguish selective from differential media and perform carbohydrate fermentation, catalase, and indole tests as time and materials permit. Two extended tasks anchor the unit. At its midpoint, each laboratory group designs, executes, and reports a controlled experiment on a question of their own about antimicrobial action, learning experimental design and formal scientific writing in the process. The unit ends with an independent unknown-identification project in which each student receives an unlabeled BSL-1 culture, designs a testing sequence, and defends an identification in a formal laboratory assessment. Labs in this unit are framed by authentic scenarios: a hospital environmental monitoring sweep, a school locker-room disinfection audit, etc. so that technique is always practiced in service of a question someone actually needs answered.

Learning Standards

NJSLS:

•HS-LS1-3. Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. (Applied to microbial responses to osmotic, thermal, and pH stress, including plasmolysis and the limits of tolerance.)

•HS-LS2-3. Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions. [Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.]

•HS-LS4-2. Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to

mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.

•HS-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations. [Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of 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. (Applied to the unknown-identification project: students decompose "identify this organism" into an ordered sequence of discriminating tests.)

Interdisciplinary Connections

Career Readiness, Life Literacies, & Key Skills *(CLKS)*:

•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). (Applied to the development of the Gram stain and of standardized antibiotic susceptibility testing as laboratory practices.)

•9.4.12.TL.2: Generate data using formula-based calculations in a spreadsheet and draw conclusions about the data. (Applied to zone-of-inhibition data tables and growth measurements.)

Computer Science & Design Thinking (*CS & DT***):**

•8.1.12.DA.5: Create data visualizations from large data sets to summarize, communicate, and support different interpretations of real-world phenomena. (Applied to the pooled class data set from the temperature, pH, oxygen, and osmotic pressure investigations, from which students build comparative growth-range graphics.)

Interdisciplinary Connections:

Mathematics:

MP.4: Model with mathematics. (Applied to constructing and interpreting bacterial growth curves, computing generation time from a doubling series, and graphing growth as a function of temperature, pH, and solute concentration.)

Learning Targets	
Unit Essential Questions: • How can you be certain that the organism growing on your plate is the organism you put there? • Why does one bacterium die from an antibiotic that another shrugs off? • What does a bacterium need from its environment, and what happens at the edges of those requirements? • How can a microbiologist name an organism she has never seen before? • What makes a laboratory result trustworthy enough for someone to act on? • When a disinfectant “works,” what exactly has been demonstrated and what has not?	**Unit Enduring Understandings:** • A pure culture is an achievement, not a starting condition. Isolation technique is the foundation of every claim that follows it. • Staining exploits real structural differences. The Gram result reports cell wall chemistry, and cell wall chemistry predicts which antibiotics can reach their target. • Growth is bounded by physical and chemical conditions. The minimum, optimum, and maximum for each factor define an organism's niche and explain where in the world it is found. • Identification is inference from a pattern of results, never a single test. Each test narrows the field, and the order of testing determines how efficiently the field narrows. • Antibiotic resistance is natural selection observed on a human timescale. Exposure to an antibiotic does not create resistant cells; it selects the resistant cells that were already present. • Microbial populations grow exponentially under favorable conditions, which is why small lapses in temperature control or timing produce large consequences in food, clinical, and water settings.

	• Controls, replication, and a stated detection limit are what separate a result from an anecdote.
Vocabulary: aseptic transfer, inoculation, inoculating loop, incineration, streak plate, isolation, isolated colony, colony morphology, pure culture, mixed culture, broth culture, agar slant, subculture, turbidity, lawn of growth, simple stain, negative stain, differential stain, Gram stain, Gram-positive, Gram-negative, peptidoglycan, lipopolysaccharide, crystal violet, mordant, decolorizer, counterstain, safranin, nigrosin, capsule, endospore, coccus, bacillus, spirillum, coccobacillus, diplococcus, streptococcus, staphylococcus, tetrad, antiseptic, disinfectant, sanitizer, bacteriostatic, bactericidal, sporicidal, contact time, antibiotic, broad spectrum, narrow spectrum, zone of inhibition, Kirby-Bauer, susceptible, intermediate, resistant, selective pressure, multidrug resistance, generation time, binary fission, lag phase, log (exponential) phase, stationary phase, death phase, mesophile, thermophile, psychrophile, obligate aerobe, obligate anaerobe, facultative anaerobe, microaerophile, aerotolerant, acidophile, neutrophile, alkaliphile, halophile, osmotic pressure, hypertonic, plasmolysis, water activity, selective medium, differential medium, enriched medium, defined medium, complex medium, fermentation, acid and gas production, Durham tube, catalase, indole, Kovac's reagent, dichotomous key, independent variable, dependent variable, control group, replication, detection limit	
Students will be able to: •Perform an aseptic transfer between broth, slant, and plate without introducing contamination, verified by a sterile control tube. •Prepare a nutrient broth culture and an agar slant culture and describe the growth pattern of each. •Prepare medium from powder: calculate the mass required for a given volume, dissolve, dispense, and autoclave. •Execute a four-quadrant streak plate that yields isolated colonies, and explain the dilution logic of each successive quadrant. •Describe colony morphology systematically using form, elevation, margin, size, texture, and pigmentation. •Prepare and interpret a simple stain and a negative stain, and state what each reveals that the other cannot. •Perform a Gram stain, identify the function of each of the four reagents, and interpret the result in terms of cell wall structure.	

•Diagnose a failed Gram stain (over-decolorized, under-decolorized, too thick a smear, culture too old) from the appearance of the field.

•Classify bacterial cells by shape and arrangement and record cell dimensions using the field-of-view method from Unit 1.

•Compare the effectiveness of handwashing, hand sanitizer, and no treatment on microbial load using a plated design with an appropriate control.

•Compare antiseptics and disinfectants at stated contact times and explain why contact time is part of the claim.

•Measure zones of inhibition around antibiotic disks, classify isolates as susceptible, intermediate, or resistant against a provided interpretive table, and account for variability between replicate plates.

•Explain the mechanisms by which antibiotics inhibit bacterial growth and reproduction and relate mechanism to the Gram result.

•Construct an evidence-based explanation of how antibiotic use selects for resistant bacterial populations.

•Design, execute, and report a controlled experiment on an antimicrobial question, identifying independent, dependent, and controlled variables and justifying replicate number.

•Write a formal laboratory report using accepted scientific conventions: purpose, methods in past-tense passive summary, data with captioned tables and figures, analysis, and conclusion.

•Plan and conduct an investigation of the effect of temperature on bacterial growth and interpret the result in terms of psychrophile, mesophile, and thermophile ranges.

•Plan and conduct an investigation of the effect of oxygen availability, and classify organisms as obligate aerobe, obligate anaerobe, or facultative anaerobe from growth distribution.

•Plan and conduct investigations of the effects of pH and of osmotic pressure on growth, and explain plasmolysis in terms of water movement.

•Distinguish selective from differential media and predict the appearance of a named organism on each.

•Perform and interpret carbohydrate fermentation, catalase, and indole tests, stating what a negative result does and does not rule out.

•Construct and use a dichotomous key to identify bacteria from a pattern of test results.

•Design and execute an ordered testing sequence to identify an unknown BSL-1 culture, and defend the identification in a formal report with explicit acknowledgment of uncertainty.

•Construct a bacterial growth curve, identify its four phases, and calculate generation time from doubling data.

•Discuss the role of bacteria in the environment using the terms autotroph, heterotroph, and decomposer, and describe fermentation as an anaerobic energy-yielding process.

Learning Activities & Differentiation: *(Amistad & Holocaust, Asian American & Pacific Islanders, Climate Change, LGBTQ and People with Disabilities, Diversity, Equity & Inclusion [DEI])*

- Hospital environmental monitoring scenario (frames the whole unit): students act as an environmental monitoring team sampling a simulated patient-care suite. Surfaces sampled in Unit 1's planned design are cultured here, isolates are streaked to purity, Gram stained, and characterized; the data set becomes the basis for the midterm performance task.
  Investigation 3: Collections of Microbes from the School Environment — executes the sampling plan designed in Unit 1, with a sterile-medium control plate on every bench.
- Investigation 4: Aseptic Technique, extended over two periods, with a sterile control tube incubated alongside every student transfer. Students who contaminate their control repeat the transfer before proceeding — the standard is technique, not speed.
- Investigation 5: Streak Plate Method of Isolating Bacteria, with a peer-scored plate gallery walk in which students diagnose one another's plates for streaking errors.
- Media preparation lab: students compute the mass of nutrient agar powder needed for their group's volume from the 23 g/L specification, prepare, autoclave, and pour their own plates. Connects stoichiometric reasoning from chemistry to bench practice.
- Investigation 6: Staining Techniques — simple stain and negative stain with nigrosin or India ink for capsule visualization.
- Investigation 7: The Gram Stain, followed by a deliberate error analysis in which each group produces one intentionally over-decolorized slide and compares it to their correct slide.
- Investigation 8: Bacterial Morphology — systematic description and sizing of B. subtilis, E. coli K-12, and M. luteus using the field-of-view reference card.

- Investigation 9: Can Your Hands and Lab Tables Be Sterilized? — framed as a locker-room disinfection audit requested by the athletic department; students must report a defensible recommendation, not just plate results.
- Investigation 10: Antiseptics vs. Disinfectants, with contact time as a manipulated variable and an explicit discussion of why product labels state contact times.
- Investigation 11: What Are Antibiotics? — disk diffusion on B. subtilis, E. coli K-12, and M. luteus, with zone measurement and interpretation against a provided reference table. Penicillium disks are used to demonstrate natural antibiotic production alongside manufactured disks.
- Antibiotic resistance case study: students analyze a published time series of resistance rates and a prescribing-volume data set, then construct a CER explanation connecting selective pressure to the observed shift (HS-LS4-2, HS-LS4-4).
- Design an Experiment (three periods): each group frames a testable antimicrobial question, submits a design for safety and feasibility approval, executes it, and presents findings in a five-minute data conference with peer questioning.

Assessment Evidence

Formative Assessments:

- Sterile control tube check after every aseptic transfer session: contamination triggers immediate re-teach and repeat, ungraded.
  Streak plate peer gallery walk with a four-item diagnostic checklist (quadrant separation, isolated colonies present, loop flamed between quadrants, agar unbroken).
- Gram stain interpretation quick-checks: students identify Gram reaction, cell shape, and arrangement from five projected fields, including two deliberately flawed preparations.
- Media calculation exit tickets (mass of powder for a given volume; dilution of a stock).
- Colony morphology description practice using standardized descriptors, cross-checked against a partner's description of the same plate.
- Zone-of-inhibition measurement calibration: all students measure the same three demonstration plates and the class compares values to surface measurement variability.

- Experimental design proposal conference: instructor reviews variables, controls, and replicate number before approval; revision required rather than a grade.
- Growth-curve and generation-time problem sets.
- Daily observation logs for the temperature, oxygen, pH, and osmotic investigations, initialed at the bench.
- Biochemical test prediction sheet completed before results are read, then compared against the actual result.

Summative Assessments:

- Aseptic Technique and Streak Plate Practical: student performs a broth-to-plate transfer and a four-quadrant streak under observation; scored on technique checklist and on whether the incubated plate yields isolated colonies and a clean control.
- Gram Stain and Morphology Practical and Quiz: student stains an assigned culture and reports Gram reaction, shape, arrangement, and estimated cell size; written portion covers reagent function, cell wall structure, and troubleshooting a failed stain.
- Controlling Microbial Growth Unit Test: antiseptics, disinfectants, sterilization, antibiotics, mechanisms of action, and resistance as natural selection. Includes a data-interpretation section with a zone-of-inhibition table and a required CER response.
- Student-Designed Antimicrobial Experiment: formal laboratory report and data conference presentation, scored with the course's seven-trait scientific writing rubric.
- Growth Requirements Unit Test: temperature, oxygen, pH, osmotic pressure, media types, and biochemical tests, with a graph-interpretation section drawn from the pooled class data.
- Unknown Identification Project: written testing-sequence proposal, laboratory records, and formal identification report with a defended conclusion and an explicit uncertainty statement.

Common Benchmark Assessments:

- Marking Period 1 Common Laboratory Skills Benchmark: aseptic transfer, streak plate, and Gram stain performed under observation against the departmental practical rubric, administered to all Honors Microbiology sections on a common date.
- Midterm Performance Assessment — “Environmental Monitoring Consult” (see Appendix A). Cumulative over Units 1 and 2. Students assume the role of a clinical or environmental laboratory microbiologist, interpret a supplied data

set of colony morphologies, Gram results, biochemical tests, growth-condition tolerances, and zone-of-inhibition measurements; identify three isolates; construct a CER explanation identifying the most probable contamination source; recommend next steps; and evaluate sources of error. Scored with the common seven-trait performance rubric.

Alternative Assessments:

- Annotated photographic technique portfolio: student documents each core skill with captioned images explaining what makes the result correct, submitted in place of one written practical.
- Recorded procedure narration in which the student performs and explains a Gram stain, substituted for the written troubleshooting section.
- Unknown identification defended in an oral examination with the instructor rather than in a written report, using the same rubric traits.
- Structured data-analysis alternative to the design experiment: student analyzes a provided authentic data set and writes the results and discussion sections only, for students whose IEP or 504 plan limits extended independent project work.
- Choice of audience for the antimicrobial experiment report: formal journal-style report, a public-health advisory memo, or a product-claim evaluation for a consumer audience.

Core Instructional & Supplemental Materials

- Van Hoeck, Kathy. Microbiology—Laboratory Activities. Flinn Scientific. Investigations 3–19.
- 2016 Microbiology Laboratory Manual, Activity #1, Section C: Inoculating microbes into/onto medium (adapted — loop sterilization performed with the infrared sterilizer rather than an open flame; culture-collection strain designations omitted).
- BSL-1 cultures: Bacillus subtilis, Escherichia coli K-12 (non-pathogenic teaching strain only), Micrococcus luteus. Ordered for arrival immediately before use; never held over between marking periods.
- Nutrient agar powder (23 g/L), nutrient broth powder, tryptic soy agar plates, sterile plastic Petri dishes, sterile screw-cap test tubes, Pyrex test tubes 16 × 150 mm.

- Gram stain kit (crystal violet, iodine mordant, decolorizer, safranin); nigrosin or India ink; 3% hydrogen peroxide (reagent grade); Kovac's reagent; glucose, lactose, and sucrose broths; 0.9% saline; laboratory-grade ethanol; distilled water.
- Twisted inoculating loops; sterile wooden applicator sticks; disposable pipettes; graduated cylinders (10, 50, 100 mL); beakers (250, 500 mL); Erlenmeyer flasks (250, 500 mL); magnetic stirrer and stir bars; stirring rods; wash bottles; labeling tape.
- Incubator; laboratory thermometers; refrigerator; Petri dish racks; test tube racks and drying rack; germicidal lamp; infrared sterilizer with slide dryer attachment; Saniclave autoclave.
- Additional media and reagents required for full unit delivery and not in the initial order: MacConkey agar and/or eosin methylene blue (EMB) plates for Investigation 16; a multi-antibiotic disk assortment for Kirby-Bauer testing in Investigation 11; immersion oil if the microscopes carry a 100× objective; a second warm incubator or improvised warm chamber for the 45–50 °C condition in Investigation 12; sterile cotton swabs for surface sampling.
- Shared class spreadsheet (Google Sheets) for pooled growth-condition data; CER response frame and seven-trait scientific writing rubric (teacher-generated, reused all year).

Accommodations and Modifications: Students with Disabilities, English Language Learners, Students at Risk of Failure, Students with 504s, Gifted & Talented Students

- Specific Strategies and Practices that Support Students with Disabilities: Students receiving Special Education programming have specific goals and objectives, as well as accommodations and modifications outlined within their Individualized Education Plans (IEP) due to an identified disability and/or diagnosis. In addition to exposure to the general education curriculum, the instruction is differentiated based upon the student's needs. The IEP acts as a supplemental curriculum guide inclusive of instructional strategies that support each learner.
- Unit-specific strategies: Every wet-lab procedure available as a short captioned video the student may replay at the bench on a tablet, so that a missed verbal direction does not end the lab period. Streak plate practiced first on a marked template plate showing quadrant boundaries before an unmarked plate is attempted. Data tables pre-formatted with units and headings supplied so cognitive effort goes to interpretation rather than table construction. The unknown identification project chunked

into four submitted checkpoints with separate due dates instead of one terminal deadline. Loop handling and hot-surface awareness explicitly taught with a hand-over-hand demonstration where an IEP indicates fine-motor need.

- Specific Strategies and Practices that Support English Language Learners: English language learner (ELL) is a national-origin-minority student who is limited-English-proficient. This term is often preferred over limited-English-proficient (LEP) as it highlights accomplishments rather than deficits.
- Unit-specific strategies: Illustrated procedure cards showing each stain step with reagent bottle photographs, so reagents are identified visually rather than by English label alone. A personal glossary maintained across the unit for the sixty-plus technical terms, with cognates flagged (e.g., colonia/colony, esterilizar/sterilize, inhibición/inhibition). Sentence frames provided for the CER response so that the argument, not the syntax, is assessed. Paired with a partner who has stronger English proficiency for the design experiment while retaining an independent role on the unknown project. Oral defense of the unknown accepted in place of extended writing where writing is the limiting factor.
- Students at Risk of Failure — unit-specific strategies: The unknown identification project scaffolded with a partially completed dichotomous key and a checkpoint conference after each of the four stages, so a student who falls behind is caught within one period rather than at submission. Laboratory work never assigned as homework, since the equipment exists only in the classroom. A duplicate set of the pooled class data provided so that a student absent on an observation day can still complete the analysis. Retake permitted on the Controlling Microbial Growth test with the higher score recorded, contingent on completing a targeted review packet. Positive contact home after the first successful Gram stain rather than only after a failure.
- Students with 504 Plans: Teachers are responsible for implementing designated services and strategies identified on a student's 504 Plan. 504 plans are formal plans that schools develop to give kids the support they need and cover any condition that limits daily activities in a major way. Students' accommodations are outlined in their individual 504 plan.
- Unit-specific strategies: Colorblind-accessible interpretation supports: Gram results confirmed by cell morphology and catalase in addition to color, and a labeled reference photograph set with the color named in text for students with color vision deficiency. Extended time on all three practical assessments. A seated bench station with all reagents within reach for students with mobility or standing limitations. Scent-reduced alternatives and increased ventilation scheduled for students with documented respiratory sensitivity to ethanol and disinfectant aerosols. Written copy of every verbal procedural change provided at the time it is announced.
- Specific Strategies and Practices that Support Gifted & Talented Students: It is critical that all teachers are able to recognize a high-ability student who may need more depth and complexity in instruction.
- Unit-specific strategies: On the unknown project, students must run one additional confirmatory test beyond the minimum and write a justification for why that test was the most informative available next step given their intermediate results. Optional extension comparing the Gram stain to a modern identification method (MALDI-TOF or 16S rRNA sequencing) and

arguing which they would choose under stated cost and turnaround constraints. Students design the interpretive reference table for the class zone-of-inhibition data rather than receiving one. Invitation to serve as data-conference discussants who prepare questions for other groups' presentations.

Unit 3

Desired Results

Unit 3 Title: The Microbial World

Unit Summary: Having learned to handle and identify bacteria, students widen the frame to the full diversity of the microbial world and to the genetics that connects it. They classify microorganisms using binomial nomenclature and consider how modern molecular evidence has revised classifications built on morphology alone. Viruses receive the most attention: structure, host specificity and attachment, DNA versus RNA genomes, lytic and lysogenic cycles, retroviral replication and reverse transcriptase, prions and viroids, and the long argument over whether viruses are alive. Students then examine fungi through three laboratory investigations. The unit closes by revisiting genetics from Biology through a microbial lens: bacterial plasmids, transformation and recombination, the Griffith and Avery–MacLeod–McCarty experiments, the role of viruses in moving genetic material, and how E. coli became the workhorse of recombinant DNA technology. Throughout, students evaluate the quality of the evidence behind classification and origin claims rather than accepting them as given.

Learning Standards

NJSLS:

- 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. [Assessment Boundary: Assessment does not include identification of specific cell or tissue types, whole body systems, specific protein structures and functions, or the biochemistry of protein synthesis.]

- 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. [Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.]
- 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. [Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.]
- HS-LS4-1. Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. [Clarification Statement: Emphasis is on a conceptual understanding of the role each line of evidence has relating to common ancestry and biological evolution. Examples of evidence could include similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.]

Interdisciplinary Connections

Career Readiness, Life Literacies, & Key Skills *(CLKS)*:

- 9.4.12.IML.2: Evaluate digital sources for timeliness, accuracy, perspective, credibility of the source, and relevance of information, in media, data, or other resources (e.g., NJSLSA.W8, Social Studies Practice: Gathering and Evaluating Sources.
- 9.4.12.CI.1: Demonstrate the ability to reflect, analyze, and use creative skills and ideas (e.g., 1.1.12prof.CR3a). (Applied to student-built physical and digital models of viral replication.)

Computer Science & Design Thinking (*CS & DT***):**

- 8.1.12.DA.6: Create and refine computational models to better represent the relationships among different elements of data collected from a phenomenon or process. (Applied to a spreadsheet or block-based model of viral replication and host cell lysis that students refine after comparing model output to published outbreak data.)

Interdisciplinary Connections:

ELA

- 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. (Applied to

primary-source excerpts from Griffith and from Avery, MacLeod, and McCarty, and to competing published hypotheses on the origin of viruses.)

Learning Targets

Unit Essential Questions:

- If a virus cannot reproduce on its own, in what sense is it or is it not alive?
- What evidence justifies putting two organisms in the same group, and what happens to a classification when the evidence changes?
- How does a virus get inside one kind of cell and not another?
- How do bacteria acquire traits they did not inherit from a parent cell?
- Why is a mold a better model for understanding decomposition than a plant is?
- Which claims about the origin of viruses are supported by evidence, and which are currently untestable?

Unit Enduring Understandings:

- Classification is a hypothesis about relationship, not a filing convention. When new evidence contradicts a grouping built on appearance, the grouping changes.
- Common ancestry is supported by converging lines of evidence — molecular sequence, cellular architecture, and biochemistry — no one of which would be sufficient alone.
- Viral specificity is a molecular fit between viral attachment proteins and host surface receptors; this fit explains host range, tissue tropism, and why most viruses cannot cross species barriers.
- The lytic and lysogenic cycles are alternative strategies with different consequences for the host population and for the movement of genetic material.
- Genetic variation in microbial populations arises from replication errors and environmental mutagens and is amplified by extremely short generation times.

	• Bacteria acquire genes horizontally as well as vertically; plasmids and viruses move genetic material between cells, which is why resistance can spread faster than a population can evolve it independently. • Fungi are heterotrophic decomposers whose external digestion and enormous surface area make them the primary recyclers of terrestrial carbon.
Vocabulary: taxonomy, binomial nomenclature, genus, species, strain, Bergey's Manual of Systematic Bacteriology, phylogeny, three-domain system, endosymbiotic theory, virus, virion, capsid, envelope, spike protein, nucleic acid core, DNA virus, RNA virus, host range, tropism, receptor, attachment, penetration, uncoating, biosynthesis, assembly, release, lytic cycle, lysogenic cycle, prophage, temperate phage, bacteriophage, retrovirus, reverse transcriptase, provirus, latency, prion, viroid, obligate intracellular parasite, protist, protozoan, pseudopod, cilia, flagella, contractile vacuole, algae, fungus, hypha, mycelium, septate, coenocytic, sporangium, conidium, conidiophore, spore, saprophyte, saprotroph, external digestion, yeast, budding, mold, dimorphic, mycosis, plasmid, transformation, transduction, conjugation, horizontal gene transfer, recombination, genotype, phenotype, mutation, mutagen, recombinant DNA, restriction enzyme, vector, genetic engineering, PTC tasting	
Students will be able to: • Write and interpret scientific names using binomial nomenclature and explain the function of a strain designation. • Explain how bacteria are classified and describe the role of Bergey's Manual of Systematic Bacteriology in identification. • Communicate the lines of empirical evidence supporting common ancestry among microorganisms, including molecular sequence data and cellular architecture. • Explain the endosymbiotic theory and evaluate the evidence offered in its support.	

- Describe the size and structural components of representative viruses and compare viral to bacterial dimensions on a common scale.
- Explain why a virus carries either DNA or RNA but never both.
- Explain viral specificity in terms of attachment proteins and host receptors, and predict the consequence of a receptor mutation.
- Define bacteriophage and compare the lytic and lysogenic cycles, including the consequences of each for the host population.
- Trace the replication of a retrovirus and explain the function of reverse transcriptase.
- Differentiate a prion from a viroid from a virus.
- Construct and defend an argument on whether viruses should be considered living, using stated criteria for life.
- Evaluate competing hypotheses on the origin of viruses and identify what evidence would distinguish among them.
- Explain the basis for classifying an organism as a protist, name three nutritional groups, and describe the logical role of protozoans.
- Identify the common characteristics of fungi and compare yeast and mold structure.
- Explain how fungi obtain nutrition by external digestion and describe their role as decomposers.
- Describe the life cycle of a mold, distinguishing asexual conidia production from sexual reproduction.
- Design and conduct an investigation into which additives or conditions retard mold growth on bread.
- Review the relationship among DNA structure, transcription, translation, and protein function, and distinguish genotype from phenotype.

Learning Activities & Differentiation: *(Amistad & Holocaust, Asian American & Pacific Islanders, Climate Change, LGBTQ and People with Disabilities, Diversity, Equity & Inclusion [DEI])*

- Scale modeling task: students build a single logarithmic scale bar placing an atom, a protein, a virus, a bacterium, a yeast cell, and a human cell in correct relative position, then use it to explain why viruses were invisible until electron microscopy.
- Investigation 20: Bread Mold Lab — run as a food-manufacturer scenario in which a bakery has asked which of four formulations resists spoilage longest. Students design the comparison, including a no-additive control, and report a recommendation with a stated confidence limit.
- Investigation 21: A Fungus Among Us? Slide Cultures of Mold — slide cultures of Penicillium and Aspergillus, observed over several

periods, with labeled drawings of conidiophore structure and a comparison of the two genera.

- Investigation 22: Yeasts Are Fungi, Too! — Saccharomyces cerevisiae budding observed and fermentation rate measured under varied sugar conditions, linking back to Unit 2 fermentation tests.
- Investigation 23: Wee Animalcules — protist survey from soil and pond material, with students keying organisms to nutritional group and estimating size using their field-of-view cards.
- Viral replication modeling: student groups build a physical or spreadsheet model of the lytic cycle, then refine it against a published one-step growth curve and account for the discrepancies (8.1.12.DA.6, 9.4.12.CI.1).
- “Are viruses alive?” structured academic controversy: students are assigned a position irrespective of their own view, argue it from stated criteria for life, then switch sides and finally write their own reasoned position. Framed explicitly as an exercise in defending a claim from criteria rather than from intuition.
- Receptor-and-key modeling activity on host specificity, extended to a discussion of why species barriers usually hold and what it means when one does not.
- Source evaluation workshop: students are given six sources on the origin of viruses — a peer-reviewed review, a university press release, a news article, a preprint, a personal blog, and an AI-generated summary — and score each on timeliness, accuracy, perspective, credibility, and relevance before using any of them (9.4.12.IML.2).
- Primary source analysis of Griffith and of Avery, MacLeod, and McCarty: students read excerpted methods and results, state what each experiment established, and identify the objection each left open (RST.11-12.8).
- Genotype and phenotype refresher using PTC taste-testing paper: students collect class phenotype data, discuss the limits of inferring genotype from phenotype, and connect the same reasoning to inferring a bacterial genotype from a biochemical test result. Discussion includes why human genetic trait surveys must be handled with care and consent, and why phenotype data are never used to sort or rank students.
- Plasmid and horizontal gene transfer modeling with paper or manipulative models, connected directly to the resistance data analyzed in Unit 2.
- Historical case reading on the development of recombinant DNA technology and the Asilomar conference, examining how scientists chose to self-regulate an emerging technology.
- Differentiation: virus structure and replication provided as a labeled diagram set at two levels of detail; tiered reading on the origin of viruses; extension for advanced students comparing bacteriophage therapy to antibiotic therapy under stated clinical constraints; graphic organizers for the three mechanisms of horizontal gene transfer.

Assessment Evidence

Formative Assessments:

- Binomial nomenclature practice and error-correction set (capitalization, italics, abbreviation of genus, strain notation).
- Virus structure labeling and scale-comparison exit tickets.
- Lytic versus lysogenic cycle sequencing cards, with students explaining the consequence of each pathway for the host population.
- Retrovirus replication flowchart with reverse transcriptase step annotated, checked for causal ordering.
- Prion, viroid, virus discrimination quick-write.
- Slide culture observation drawings with instructor feedback on labeling accuracy across successive periods.
- Protist identification checkpoint using student drawings and size estimates.
- Source evaluation scorecards submitted before the research task begins.
- Griffith and Avery primary-source analysis organizer.
- Horizontal gene transfer mechanism sorting task.

Summative Assessments:

- Virology Test: viral structure, specificity, genome types, replication cycles, retroviruses, prions and viroids, and a constructed-response item requiring an argument on whether viruses are alive, scored for use of stated criteria.
- Fungi and Protists Laboratory Report: comparative report on Penicillium, Aspergillus, and Saccharomyces drawn from Investigations 21 and 22, including labeled original drawings, size estimates, and a section on the ecological role of fungi as decomposers.
- Bread Mold Investigation and Recommendation Memo: experimental design, data, and a client-facing recommendation with stated limitations (Investigation 20).
- Microbial Genetics and Classification Test: taxonomy, three domains, endosymbiotic theory, plasmids, transformation, transduction, conjugation, the Griffith and Avery experiments, and recombinant DNA, including a claim-defense item on the origin of heritable variation in bacterial populations.
- Viral Replication Model with written justification of each refinement made after comparison to published data. Assessed as a component of the Virology Test rather than as a separate summative, in order to hold the unit to 17 instructional periods.

Common Benchmark Assessments:

- Marking Period 3 Common Written Benchmark: Assessment on microbial diversity and genetics.
- Cumulative CER Checkpoint: a single data-interpretation prompt drawn from Unit 3 content but scored with the full midterm and final rubric, used diagnostically to identify which rubric traits need reteaching before the final performance assessment.

Alternative Assessments:

- Physical or animated model of a viral replication cycle with recorded narration, substituted for the constructed-response section of the virology test.
- Annotated microscopy image portfolio with captions explaining diagnostic features, substituted for the fungi and protists written report.
- Structured debate participation with a written position statement, substituted for the “are viruses alive” essay.
- Concept map of horizontal gene transfer mechanisms with written explanations at each link, substituted for the corresponding test section.
- Choice of research product for the source-evaluation task: annotated bibliography, podcast segment, or written brief.

Core Instructional & Supplemental Materials

- Van Hoeck, Kathy. Microbiology—Laboratory Activities. Flinn Scientific. Investigations 20–23.
- BSL-1 cultures and specimens: Saccharomyces cerevisiae, Penicillium, Aspergillus, soil and pond samples, prepared protist slides. Live fungal cultures ordered for arrival immediately before use.
- Bread without preservatives plus comparison formulations; sterile Petri dishes; nutrient agar; glass slides and cover slips; lens paper; sterile wooden applicator sticks; labeling tape.
- PTC taste-test paper (100 per pack) for the genotype–phenotype refresher; genetics manipulatives or paper plasmid models.
- Digital microscope camera for shared projection and comparison of student slide cultures.

- Primary and secondary sources: excerpted Griffith (1928) and Avery, MacLeod, and McCarty (1944) methods and results; a peer-reviewed review on the origin of viruses; the source-evaluation source set (six mixed-credibility items, teacher-curated); historical account of the 1975 Asilomar conference.
- NCBI Taxonomy Browser and a 16S rRNA sequence-comparison activity (browser-based) for the classification-evidence task.
- Spreadsheet or block-based modeling environment for the viral replication model.

Accommodations and Modifications: Students with Disabilities, English Language Learners, Students at Risk of Failure, Students with 504s, Gifted & Talented Students

Specific Strategies and Practices that Support Students with Disabilities: Students receiving Special Education programming have specific goals and objectives, as well as accommodations and modifications outlined within their Individualized Education Plans (IEP) due to an identified disability and/or diagnosis. In addition to exposure to the general education curriculum, the instruction is differentiated based upon the student's needs. The IEP acts as a supplemental curriculum guide inclusive of instructional strategies that support each learner.

Unit-specific strategies: Viral replication presented as a manipulable physical sequence before it is presented as a diagram, so that the causal order is built kinesthetically. Slide culture observations recorded on a pre-structured drawing template with the required labels pre-listed. Extended observation windows scheduled so that a student who needs longer at the microscope is not competing for time. Vocabulary load reduced by teaching the three horizontal gene transfer mechanisms across three separate periods rather than in one, with a cumulative organizer. Verbal responses accepted for the “are viruses alive” argument with the written statement scribed.

Specific Strategies and Practices that Support English Language Learners: English language learner (ELL) is a national-origin-minority student who is limited-English-proficient. This term is often preferred over limited-English-proficient (LEP) as it highlights accomplishments rather than deficits.

Unit-specific strategies: Word wall built for the unit's Greek and Latin roots (myco-, phage-, -trophy, sapro-, conidi-), which unlocks a large share of the vocabulary at once. Cognate list provided (virus/virus, capside/capsid, hifa/hypha,

levadura/yeast, transformación/transformation). Debate participation scaffolded with pre-written argument frames and a preparation period with a same-language partner where available. Primary-source excerpts provided in a simplified parallel version alongside the original so the student engages the actual reasoning without being blocked by 1928 prose. Labeled diagrams used as the primary assessment format wherever a written description would otherwise be required.

Students at Risk of Failure — unit-specific strategies: The bread mold investigation used as a low-stakes re-entry point for students who struggled in Unit 2, since it requires patience rather than fine technique and yields visible results. Research task broken into three graded checkpoints with a provided source set, eliminating the open-ended search that most often stalls progress. A completed model virus provided as a reference for students building their own. Test corrections offered for partial credit recovery on both unit tests, requiring a written explanation of the error rather than the correct answer alone. Progress conference scheduled at the midpoint of the unit.

Students with 504 Plans: Teachers are responsible for implementing designated services and strategies identified on a student's 504 Plan. 504 plans are formal plans that schools develop to give kids the support they need and cover any condition that limits daily activities in a major way. Students' accommodations are outlined in their individual 504 plan.

Unit-specific strategies: Slide culture and protist observations available as high-resolution projected images and shared digital files for students whose vision, attention, or documented condition makes extended eyepiece work difficult. Extended time and a distraction-reduced setting for both unit tests. Mold and fungal culture work modified for students with documented mold or spore allergies: sealed plates observed through the lid only, or the digital image set substituted entirely, with no reduction in the assessable content. Debate participation modified to a written or small-group format for students whose 504 plan addresses anxiety in whole-class speaking.

Specific Strategies and Practices that Support Gifted & Talented Students: It is critical that all teachers are able to recognize a high-ability student who may need more depth and complexity in instruction.

Unit-specific strategies: Extension comparing bacteriophage therapy to conventional antibiotic therapy, evaluated against stated clinical criteria and constraints, and connected to the resistance data from Unit 2. Independent analysis of a real 16S rRNA sequence alignment to construct a small phylogeny and argue a classification decision from molecular evidence. Students critique the peer-reviewed source in the source-evaluation set rather than only the weak sources, identifying its actual limitations. Optional seminar on the Asilomar conference as a case in scientific self-governance, presented to the class.

Unit 4

Desired Results

Unit 4 Title: Microbes and Man

Unit Summary:

This unit turns to the roughly one percent of microorganisms that cause disease and to the human systems built to detect, treat, and prevent them. Students examine the host–parasite relationship, Koch's postulates, routes of transmission, vectors, and the normal flora that occupies the human body including which body sites should be sterile and what it means when an organism appears where it does not belong. They then work through immunity in sequence: physical and chemical barriers, the inflammatory response and its four cardinal signs, specific defense, humoral versus cell-mediated immunity, antigens and antibodies, the primary and secondary response, and the basis of vaccination. Two viral case studies, HIV and Ebola, are compared in detail because their transmission dynamics, replication strategies, and public health responses differ so instructively. The unit's second half is epidemiology: epidemic, endemic, and pandemic; mortality versus morbidity; reservoirs and carriers; the stages of infection; healthcare-associated infection; and the working methods of an epidemiologist. Students run an outbreak investigation using a line list and an epidemic curve, and each student researches and presents a microbial disease. Bioethics and public health policy are treated directly (vaccine hesitancy, antimicrobial stewardship, equitable access to treatment, and the credibility of health information in the media) with students required to argue from evidence.

Learning Standards

NJSLS:

- HS-LS1-3. Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis. [Clarification Statement: Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.] (Applied to fever, inflammation, and the primary and secondary immune response as regulated feedback systems.)

- HS-LS2-6. Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. [Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption or sea level rise.] (Applied to the human microbiome as an ecosystem and to the consequences of disrupting it.)
- HS-LS4-4. Construct an explanation based on evidence for how natural selection leads to adaptation of populations. [Clarification Statement: Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems (such as ranges of seasonal temperature, long-term climate change, acidity, light, geographic barriers, or evolution of other organisms) contribute to a change in gene frequency over time, leading to adaptation of populations.]
- HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species. [Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.] (Applied to emerging infectious disease and the conditions that produce spillover.)
- 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. (Applied to antimicrobial resistance and to vaccine distribution.)

Interdisciplinary Connections

Career Readiness, Life Literacies, & Key Skills *(CLKS)*:

- 9.4.12.IML.7: Develop an argument to support a claim regarding a current workplace or societal/ethical issue such as climate change (e.g., NJSLSA.W1, 7.1.AL.PRSNT.4). (Applied to antimicrobial stewardship and to equitable access to vaccines and treatment.)
- 9.4.12.IML.8: Evaluate media sources for point of view, bias, and motivations (e.g., NJSLSA.R6, 7.1.AL.IPRET.6). (Applied to public health messaging and to health misinformation during outbreaks.)

- 9.2.12.CAP.3: Investigate how continuing education contributes to one's career and personal growth. (Applied to the continuing-education and recertification requirements of clinical laboratory and public health professionals.)

Computer Science & Design Thinking (*CS & DT*):

- 8.1.12.IC.1: Evaluate the ways computing impacts personal, ethical, social, economic, and cultural practices. (Applied to digital disease surveillance, contact tracing, and the privacy trade-offs of outbreak data collection.)
- 8.2.12.EC.1: Analyze controversial technological issues and determine the degree to which individuals, businesses, and governments have an ethical role in decisions that are made. (Applied to vaccine mandates, antibiotic use in agriculture, and pricing of essential antimicrobials.)

Interdisciplinary Connections:

ELA

- RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (Applied to the outbreak investigation, in which students must reconcile a line list, an epidemic curve, laboratory results, an interview transcript, and a news report.)

Learning Targets

Unit Essential Questions:

- What has to be true before we can say that a particular microorganism caused a particular disease?
- Why does the same pathogen produce serious illness in one person and no symptoms in another?
- Why is the body's inflammatory response both protective and dangerous?

Unit Enduring Understandings:

- Establishing causation requires more than correlation; Koch's postulates formalized that standard, and the cases where they fail are as instructive as the cases where they hold.
- Disease is an outcome of the interaction between pathogen virulence, dose, route of entry, and host defense, not a property of the microorganism alone.

• How does an epidemiologist find the source of an outbreak without ever seeing the pathogen? • Why did HIV become a global pandemic while Ebola outbreaks have so far remained regional? • Whose responsibility is it to slow antimicrobial resistance: the patient's, the prescriber's, the farmer's, or the government's? • How do you tell a credible public health claim from a persuasive one?	• The inflammatory response is a feedback system whose set points protect the body within limits and injure it when the response is excessive or sustained. • Immunological memory is why vaccination works: a secondary response is faster and larger because the population of specific lymphocytes has already been expanded. • The human microbiome is an ecosystem; the resident community normally holds a stable composition, and disruption of that community produces predictable consequences. • Transmission dynamics (not lethality) determine whether an outbreak becomes a pandemic. A highly lethal pathogen with a short infectious period can be easier to contain than a mild one with a long one. • Antimicrobial resistance is a global challenge with quantifiable criteria and hard constraints; slowing it requires coordinated action across clinical, agricultural, and regulatory systems. • Public health decisions balance individual liberty against collective risk, and reasonable people weigh those values differently even when they agree on the evidence.
Vocabulary: pathogen, parasite, host, host–parasite relationship, virulence, virulence factor, pathogenicity, infectious dose, toxin, exotoxin, endotoxin, opportunistic pathogen, Koch's postulates, germ theory, transmission, direct contact, indirect	

contact, droplet, airborne, fomite, vehicle, vector, biological vector, mechanical vector, zoonosis, spillover, normal flora, microbiota, microbiome, resident flora, transient flora, sterile site, nonspecific defense, innate immunity, physical barrier, chemical barrier, lysozyme, mucous membrane, phagocytosis, inflammation, cardinal signs, fever, pyrogen, specific defense, adaptive immunity, antigen, antibody, immunoglobulin, epitope, lymphocyte, B cell, T cell, helper T cell, cytotoxic T cell, plasma cell, memory cell, humoral immunity, cell-mediated immunity, primary immune response, secondary immune response, immunological memory, active immunity, passive immunity, naturally acquired immunity, artificially acquired immunity, vaccination, attenuated, inactivated, subunit vaccine, mRNA vaccine, herd immunity, autoimmunity, immunodeficiency, allergy, HIV, AIDS, retrovirus, CD4, opportunistic infection, antiretroviral therapy, Ebola virus, hemorrhagic fever, case fatality rate, epidemiology, epidemic, endemic, pandemic, outbreak, incidence, prevalence, morbidity, mortality, case fatality rate, reservoir, carrier, asymptomatic carrier, index case, incubation period, prodromal period, illness period, convalescence, line list, epidemic curve, contact tracing, quarantine, isolation, healthcare-associated (nosocomial) infection, antimicrobial stewardship, surveillance.

Students will be able to:

- Define parasite and pathogen and distinguish parasite–host relationships from mutualistic and commensal symbioses.
- List and explain Koch's postulates and identify a disease for which they cannot be satisfied, explaining why.
- Describe the role of Pasteur, Lister, and Koch in establishing the germ theory of infectious disease.
- Explain the basic routes by which infectious diseases are transmitted and classify given scenarios by route.
- Define vector and distinguish biological from mechanical vectors.
- Describe the normal flora of major body sites, identify which sites are normally sterile, and explain the clinical significance of finding an organism at a sterile site.
- Evaluate claims and evidence about the human microbiome as an ecosystem whose composition is stable under normal conditions and altered by disruption.
- Describe the body's nonspecific defenses, including physical barriers, chemical barriers, and phagocytosis.
- Explain the inflammatory response and its four cardinal signs, and account for each sign in terms of the underlying physiological change.
- Explain fever as a regulated feedback response and evaluate evidence on its protective and harmful effects.

- Compare nonspecific to specific defense and explain what specificity adds.
- Describe how the body acquires immunity and distinguish active from passive and naturally from artificially acquired immunity.
- Distinguish antigens from antibodies and describe antibody structure and function.
- Compare humoral and cell-mediated immunity and identify the lymphocytes associated with each.
- Distinguish the primary from the secondary immune response using antibody titer curves and explain the basis of vaccination.
- Identify disorders of the immune system, including autoimmune conditions, immunodeficiencies, and allergy.
- Explain the pathogenicity of HIV: how it enters the body, its replication cycle, transmission routes, stages of infection, and the basis of antiretroviral therapy.
- Explain the pathogenicity of Ebola virus and account for the differences between it and HIV in transmission and containment.
- Model and compare the transmission dynamics of HIV and Ebola and explain why case fatality rate alone does not predict pandemic potential.
- Describe the role of the epidemiologist in public health and the tools of an outbreak investigation.
- Distinguish epidemic, endemic, and pandemic, and distinguish morbidity from mortality and incidence from prevalence.
- Distinguish reservoir from carrier and describe the stages of the infection cycle.
- Construct and interpret an epidemic curve from a line list and use it to infer a likely exposure window and transmission pattern.
- Explain healthcare-associated infection and the role of the hospital environment in the spread of disease, drawing on the Unit 2 environmental monitoring data.
- Analyze antimicrobial resistance as a global challenge and specify qualitative and quantitative criteria and constraints for solutions.
- Research a microbial disease and present findings to the class, with sources evaluated for credibility and bias.
- Develop an evidence-based argument on a public health issue and evaluate the point of view and motivation of media sources reporting on it.

Learning Activities & Differentiation: *(Amistad & Holocaust, Asian American & Pacific Islanders, Climate Change, LGBTQ and People with Disabilities, Diversity, Equity & Inclusion [DEI])*

- Koch's postulates applied and broken: students walk the postulates through a case where they work, then analyze two where they fail (an obligate intracellular pathogen that cannot be cultured, and an asymptomatic carrier), and revise the standard accordingly.
- Normal flora mapping: students annotate a body outline with expected resident organisms by site and mark sterile sites, then are given three culture reports and must decide which represents contamination, which colonization, and which infection. Directly reuses the identification skills from Unit 2.
- Microbiome-as-ecosystem claim evaluation: students evaluate a set of claims about probiotics and antibiotic-associated disruption against provided evidence of varying quality, and rate each claim as supported, overstated, or unsupported (HS-LS2-6, 9.4.12.IML.8).
- Inflammation cardinal-signs investigation: students account for redness, heat, swelling, and pain from vascular changes, then read a case of sepsis to examine what happens when the response is systemic and unregulated (HS-LS1-3).
- Investigation 24: The Effect of Lysozyme — nonspecific chemical defense demonstrated with egg white lysozyme against M. luteus, connecting a molecule to a measurable zone of inhibition.
- Antigen–antibody specificity modeling: paper or manipulative modeling of epitope recognition, clonal expansion, and memory cell formation. This replaces the Ouchterlony immunodiffusion technique in the source manual, which requires antisera not appropriate to a BSL-1 high school budget; the modeling activity targets the same objectives at lower cost and risk.
- Antibody titer graph analysis: students interpret primary and secondary response curves, then predict the curve produced by a two-dose vaccine schedule and explain the interval between doses.
- Vaccine platform comparison: attenuated, inactivated, subunit, and mRNA vaccines compared on a criteria matrix (cold chain requirement, manufacturing time, dose schedule, suitability for immunocompromised recipients), leading to an argued recommendation for a hypothetical outbreak scenario (HS-ETS1-1).
- HIV and Ebola comparative case study: students build a side-by-side profile covering genome type, replication, transmission route, infectious period, case fatality rate, and public health response, then model transmission for each and explain the divergent outcomes. Treated with clinical seriousness; the history of the HIV/AIDS epidemic includes the stigmatization of affected communities and how that stigma delayed public health response, examined as a case in which social response shaped biological outcome (DEI; LGBTQ).
- Investigation 26: Disease Detectives: Who's Got the Bug? — a simulated transmission exercise, debriefed by having students reconstruct the transmission chain from the data they generated and identify the index case.
- Outbreak investigation with a line list: students receive a line list of cases with onset times and exposures, construct an epidemic curve, calculate attack rates by exposure, and identify the most probable vehicle. They must reconcile the line list with a laboratory report, an interview transcript, and a news article that gets one detail wrong (RST.11-12.7).

- Healthcare-associated infection audit: students revisit their own Unit 2 environmental monitoring data and write a recommendation to an infection prevention committee, with the recommendation evaluated against cost and feasibility constraints.
- Antimicrobial resistance policy analysis: students specify criteria and constraints for reducing resistance, then evaluate three policy levers (prescriber guidelines, restrictions on agricultural use, and incentives for new drug development) against those criteria and argue a priority (HS-ETS1-1, 8.2.12.EC.1, 9.4.12.IML.7).
- Digital surveillance and privacy: students examine how contact tracing and syndromic surveillance systems work and evaluate the privacy trade-offs, taking and defending a position (8.1.12.IC.1).
- Disease research project and presentation: each student researches one microbial disease (etiologic agent, transmission, pathogenesis, epidemiology, treatment, prevention, and current status) and presents to the class. Assigned diseases deliberately span global regions and include diseases of poverty that receive limited research funding, so that the class confronts the gap between disease burden and research investment (DEI; Global and Cultural Awareness).
- Public health career strand: the continuing-education and recertification requirements of medical laboratory scientists and public health professionals are examined, connecting to the Unit 1 careers work (9.2.12.CAP.3).
- Differentiation: immunity taught with a consistent visual metaphor maintained across all lessons; tiered case studies at three complexity levels for the outbreak investigation; disease research project offered with a structured template or fully open format; extension for advanced students requiring calculation of a basic reproduction number from provided data.

Assessment Evidence

Formative Assessments:

- Koch's postulates application organizer, including the two cases where the postulates fail.
- Transmission route classification quick-sorts (fifteen scenarios).
- Normal flora body map with sterile sites marked; three-report triage exercise (contamination, colonization, infection).
- Cardinal signs of inflammation explanation exit ticket requiring a physiological cause for each sign.
- Humoral versus cell-mediated immunity comparison chart, checked for correct lymphocyte assignment.
- Antibody titer curve interpretation problems, including the two-dose prediction.
- HIV replication cycle sequencing task with the reverse transcriptase and integration steps annotated.

- Epidemiological vocabulary application set (incidence versus prevalence, morbidity versus mortality, epidemic versus endemic) using real reported figures.
- Epidemic curve construction checkpoint from a short practice line list.
- Attack rate calculations by exposure category.
- Media source bias annotation on two articles covering the same outbreak.
- Disease research project checkpoints: source list with credibility notes, outline, draft visual.

Summative Assessments:

- Host–Pathogen and Immunity Test: virulence, transmission, normal flora, nonspecific and specific defense, humoral and cell-mediated immunity, immunological memory, vaccination, and immune disorders. Includes a titer-curve data interpretation item scored for CER.
- HIV and Ebola Comparative Analysis: written comparison with a transmission model and an explanation of why case fatality rate does not predict pandemic potential.
- Outbreak Investigation Report: epidemic curve, attack rate table, CER identification of the most probable vehicle, recommended next steps, and a sources-of-error section. This is the principal rehearsal for the final performance assessment and uses the identical rubric.
- Microbial Disease Research Project and Presentation: scored for scientific accuracy, source credibility and citation, treatment of epidemiology and prevention, and clarity of presentation.
- Public Health Position Paper: an evidence-based argument on antimicrobial stewardship, vaccine policy, or surveillance and privacy, requiring engagement with the strongest counterargument (9.4.12.IML.7). Drafted largely outside class; one in-class research and source-evaluation period is provided.

Common Benchmark Assessments:

- Marking Period 4 Common Written Benchmark on infectious disease and immunity administered on a common date, including one CER data-interpretation item.
- Outbreak Investigation Report performance benchmark for the marking period, scored with the same rubric applied to the midterm and final so that trait-level growth is tracked across all four marking periods.

Alternative Assessments:

- Recorded or live oral defense of the outbreak investigation conclusion in place of the written report, scored with the same traits.
- Public health infographic, public service announcement, or podcast segment substituted for the position paper.
- Annotated model or animation of the HIV replication cycle substituted for the written comparative analysis.
- Disease research presented as a patient-education pamphlet, a clinician-facing brief, or a documentary-style video, student's choice.
- Structured graphic organizer completed in an interview format with the instructor, substituted for the immunity test's extended response section.

Core Instructional & Supplemental Materials

- Van Hoeck, Kathy. Microbiology—Laboratory Activities. Flinn Scientific. Investigation 24: The Effect of Lysozyme; Investigation 26: Disease Detectives: Who's Got the Bug? (Investigation 25, the Ouchterlony technique, is replaced by an antigen–antibody modeling activity — see Learning Activities.)
- CDC resources: Principles of Epidemiology in Public Health Practice (Lesson 1 and Lesson 6, adapted), Epidemic Intelligence Service case studies, Solve the Outbreak, and current surveillance summaries.
- World Health Organization Ebola outbreak situation reports; UNAIDS global HIV data; CDC HIV Surveillance Report.
- Teacher-generated line lists and epidemic curve data sets at three complexity tiers.
- Egg white or lysozyme preparation, M. luteus culture, nutrient agar plates, sterile applicator sticks for Investigation 24.
- Antigen–antibody modeling manipulatives or printed epitope-and-receptor card sets.
- Excerpt from Preston, R. The Hot Zone (optional supplementary reading, teacher-selected excerpt only).
- Media source set for bias analysis: two contrasting news articles on a single outbreak plus the underlying agency report.
- New Jersey Department of Health communicable disease reporting materials and reportable disease list.
- Seven-trait CER performance rubric and CER response frame (course-wide).

Accommodations and Modifications:
Students with Disabilities, English Language Learners,
Students at Risk of Failure, Students with 504s, Gifted & Talented Students

Specific Strategies and Practices that Support Students with Disabilities: Students receiving Special Education programming have specific goals and objectives, as well as accommodations and modifications outlined within their Individualized Education Plans (IEP) due to an identified disability and/or diagnosis. In addition to exposure to the general education curriculum, the instruction is differentiated based upon the student's needs. The IEP acts as a supplemental curriculum guide inclusive of instructional strategies that support each learner.

Unit-specific strategies: One consistent visual metaphor for the immune system maintained across every lesson in the unit, so that new content attaches to a familiar structure rather than a new one each period. The outbreak investigation supplied with a partially completed line list and a pre-drawn epidemic curve axis with intervals labeled. Immunity vocabulary front-loaded on a cumulative reference sheet the student keeps and adds to. Disease research project scaffolded with a section-by-section template and staggered internal deadlines. Presentation delivered to the instructor and a small group rather than the full class where an IEP addresses public speaking.

Specific Strategies and Practices that Support English Language Learners: English language learner (ELL) is a national-origin-minority student who is limited-English-proficient. This term is often preferred over limited-English-proficient (LEP) as it highlights accomplishments rather than deficits.

Unit-specific strategies: Immunity content taught with labeled diagrams as the primary representation and text as support, reversing the usual ratio. Cognate bridge for the unit's heavily Latinate vocabulary (inflamación/inflammation, inmunidad/immunity, anticuerpo/antibody, vacuna/vaccine, epidemia/epidemic). Line list column headers glossed in the student's home language. Position paper argument scaffolded with claim, evidence, and counterargument frames, with credit assigned to the reasoning rather than to idiomatic fluency. Disease research permitted on a disease endemic to the student's country or region of origin, using sources in the home language alongside English sources — which strengthens the project's global scope for the whole class.

Students at Risk of Failure — unit-specific strategies: Outbreak investigation completed in a structured group with assigned roles, so that a student who has disengaged has a defined and visible contribution. Disease research project source set curated to five approved sources to remove the open search barrier. Weekly grade check with a printed progress sheet the student initials.

Position paper drafted in class rather than assigned as homework, since take-home writing is the most commonly missed assignment. Explicit re-entry plan for any student returning from extended absence, since this unit is heavily sequential.

Students with 504 Plans: Teachers are responsible for implementing designated services and strategies identified on a student's 504 Plan. 504 plans are formal plans that schools develop to give kids the support they need and cover any condition that limits daily activities in a major way. Students' accommodations are outlined in their individual 504 plan.

Unit-specific strategies: Content warning and an alternative pathway offered before the HIV/AIDS and Ebola case studies for students whose 504 plan addresses anxiety or who have a personal or family connection to serious illness; the alternative covers the same objectives through a different pathogen pair. Extended time and a separate setting for both unit tests. Presentation to a recorded video submission rather than live delivery where anxiety is documented. Scheduled movement breaks during the extended outbreak investigation periods. Enlarged and high-contrast line lists and epidemic curves for students with visual impairment.

Specific Strategies and Practices that Support Gifted & Talented Students: It is critical that all teachers are able to recognize a high-ability student who may need more depth and complexity in instruction.

Unit-specific strategies: Students calculate a basic reproduction number from provided outbreak data and use it to argue which of two interventions would more effectively interrupt transmission. Extension analyzing a real published outbreak investigation report and critiquing the investigators' reasoning and stated limitations. Independent research into the economics of antimicrobial development — why the pipeline has thinned despite rising resistance — presented as a policy brief. Students serve as discussants for classmates' disease presentations, preparing substantive questions in advance.

Unit 5

Desired Results

Unit 5 Title: Microbes and the Environment

Unit Summary:

The final unit recovers the perspective the course opened with: the overwhelming majority of microorganisms are beneficial or neutral, and the biosphere depends on them. Students examine food microbiology — spoilage as the food industry's largest economic loss, preservation methods and the principle behind each, the factors governing microbial

growth in food, and the distinction between food infection and food intoxication, which they learn to make from onset-time data. They study soil microbiology and the microbial basis of decomposition and soil formation, and they investigate nitrogen fixation directly. Water microbiology supplies the unit's quantitative core: students master serial dilution and the pour plate technique, compute colony-forming units per milliliter, compare results against regulatory standards, and use coliforms as indicator organisms rather than as pathogens. The unit closes on applied and industrial microbiology — fermented foods, pharmaceuticals, enzymes, agricultural applications, and bioremediation — and on the bioethics of industrial and engineered microorganisms. The final performance assessment sits at the end of this unit and draws on the whole year.

Learning Standards

NJSLS:

- HS-LS2-3. Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions. [Clarification Statement: Emphasis is on conceptual understanding of the role of aerobic and anaerobic respiration in different environments.]
- HS-LS2-4. Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem. [Clarification Statement: Emphasis is on using a mathematical model of stored energy in biomass to describe the transfer of energy from one trophic level to another and that matter and energy are conserved as matter cycles and energy flows through ecosystems. Emphasis is on atoms and molecules such as carbon, oxygen, hydrogen and nitrogen being conserved as they move through an ecosystem.]
- HS-LS2-5. Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere. [Clarification Statement: Examples of models could include simulations and mathematical models.]
- HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. [Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.]
- 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 possible social, cultural, and environmental impacts.

Interdisciplinary Connections

Career Readiness, Life Literacies, & Key Skills *(CLKS)*:

- 9.4.12.CT.2: Explain the potential benefits of collaborating to enhance critical thinking and problem solving (e.g., 1.3E.12profCR3.a). (Applied to the multi-team water quality investigation, in which each team's dilution series contributes to a single class determination.)
- 9.4.12.GCA.1: Collaborate with individuals to analyze a variety of potential solutions to climate change effects and determine why some solutions (e.g., political. economic, cultural) may work better than others (e.g., SL.11-12.1., HS-ETS1-1, HS-ETS1-2, HS-ETS1-4, 6.3.12.GeoGI.1, 7.1.IH.IPERS.6, 7.1.IL.IPERS.7, 8.2.12.ETW.3).

Computer Science & Design Thinking (*CS & DT***):**

- 8.2.12.ETW.2: Synthesize and analyze data collected to monitor the effects of a technological product or system on the environment. (Applied to wastewater treatment performance data and to plate count data from a receiving water body.)
- 8.2.12.ETW.3: Identify a complex, global environmental or climate change issue, develop a systemic plan of investigation, and propose an innovative sustainable solution.

Interdisciplinary Connections:

Mathematics

- MP.2: Reason abstractly and quantitatively. (Applied to serial dilution, dilution factor arithmetic, colony-forming unit computation, the countable-plate range, and comparison of a computed result against a regulatory threshold.)

Learning Targets

Unit Essential Questions:	**Unit Enduring Understandings:** • Every food preservation method works by removing one of the requirements for microbial growth —

• Why is food spoilage the food industry's largest single economic loss, and what does every preservation method actually do? • How can you tell from onset times alone whether people were sickened by an organism or by a toxin it left behind? • How do you count something you cannot see, and how confident can you be in the number? • Why do we test drinking water for coliforms rather than for the pathogens we are actually worried about? • What would happen to the nitrogen and carbon cycles if microorganisms stopped working? • When is releasing or engineering a microorganism a responsible solution to an environmental problem, and when is it not?	water, favorable temperature, favorable pH, or nutrients — or by adding an inhibitor. Knowing the requirement explains the method. • Food infection and food intoxication are distinguishable from epidemiological data alone: incubation period reflects whether an organism must establish itself or a preformed toxin is already present. • A plate count is an estimate with a defined countable range and a stated dilution factor; a number reported without its dilution and its range is not a result. • Indicator organisms are used because they are easier and safer to detect than pathogens and because their presence signals the same contamination pathway. • Matter is conserved as it cycles; microbial decomposition and nitrogen fixation are the steps that return carbon and nitrogen to biologically available forms, and without them the cycles halt. • Anaerobic and aerobic processes yield different amounts of energy and different products, which is why wastewater treatment, composting, and food fermentation are all engineered around oxygen availability. • Applying microorganisms to an environmental problem is an engineering decision subject to

	criteria and constraints — effectiveness, cost, containment, and the risk of unintended consequences.

Vocabulary:
food microbiology, food spoilage, shelf life, water activity, food infection, food intoxication, preformed toxin, incubation period, pasteurization, sterilization, canning, retort, refrigeration, freezing, dehydration, lyophilization, curing, salting, pickling, fermentation, irradiation, high-pressure processing, chemical preservative, hurdle technology, cold chain, temperature abuse, danger zone, HACCP, critical control point, soil microbiology, humus, decomposition, decomposer, saprotroph, mineralization, biogeochemical cycle, carbon cycle, nitrogen cycle, nitrogen fixation, nitrogen-fixing bacteria, Rhizobium, root nodule, nitrification, denitrification, ammonification, symbiosis, mutualism, rumen, ruminant, aquatic microbiology, potable water, indicator organism, coliform, fecal coliform, total coliform, most probable number, serial dilution, dilution factor, dilution series, pour plate, spread plate, standard plate count, heterotrophic plate count, colony-forming unit (CFU), countable range, plate count agar, sewage, wastewater treatment, primary treatment, secondary treatment, activated sludge, biological oxygen demand (BOD), eutrophication, biotechnology, industrial microbiology, bioreactor, fermenter, single-cell protein, bioremediation, biodegradation, biofuel, biopesticide, genetically engineered organism, containment

Students will be able to:

- Identify food spoilage as the most serious economic problem in the food processing industry and quantify the scale of the loss from provided data.
- Describe the major food preservation techniques and explain each in terms of which requirement for microbial growth it removes or which inhibitor it adds.
- Explain the crucial factors affecting microbial growth in foods, including water activity, pH, temperature, and available nutrients.
- Distinguish a food infection from a food intoxication and make the distinction from onset-time data in a case report.

- Apply the concept of temperature abuse to a food-handling timeline and predict the microbial consequence using the growth curve reasoning from Unit 2.
- Describe the role of microorganisms as decomposers and in soil formation.
- Explain the role of bacteria in biogeochemical cycles, with particular attention to nitrogen fixation.
- Investigate nitrogen fixation experimentally and identify nodule bacteria microscopically.
- Use mathematical representations to support a claim about the cycling of matter and the flow of energy among organisms.
- Develop a model illustrating the role of photosynthesis and cellular respiration in cycling carbon among the biosphere, atmosphere, hydrosphere, and geosphere.
- Construct and revise an evidence-based explanation of matter cycling and energy flow under aerobic versus anaerobic conditions.
- Discuss the role of bacteria in the rumen ecosystem and in the evolution of ruminant digestion.
- Perform a serial dilution using correct pipetting technique and record the dilution factor at each step.
- Perform the pour plate technique and produce countable plates.
- Calculate colony-forming units per milliliter from plate count data, applying the countable range and the dilution factor correctly.
- Compare a computed plate count against a regulatory or advisory standard and state whether the sample passes, with the uncertainty of the estimate acknowledged.
- Explain why coliforms are used as indicator organisms in water testing and what a positive coliform result does and does not establish.
- Describe the role of microorganisms in sewage and wastewater treatment and distinguish primary from secondary treatment.
- Analyze wastewater or receiving-water monitoring data and evaluate the performance of the treatment system.
- Describe the role of microbes in biotechnology, distinguishing traditional microbial technology from technology using engineered organisms.
- List industrial products derived from microorganisms and describe agricultural applications of microbial biotechnology.

- Discuss environmental applications of industrial microbiology, including bioremediation.
- Design, evaluate, and refine a proposed microbial solution for reducing a human impact on the environment, evaluated against prioritized criteria and constraints.
- Analyze the ethical dimensions of releasing or engineering microorganisms and determine the roles of individuals, industry, and government in the decision.

Learning Activities & Differentiation: *(Amistad & Holocaust, Asian American & Pacific Islanders, Climate Change, LGBTQ and People with Disabilities, Diversity, Equity & Inclusion [DEI])*

- Preservation reverse-engineering: students examine the labels and processing descriptions of eight preserved foods and, for each, name the growth requirement removed or the inhibitor added. Establishes the unit's organizing principle in one period.
- Investigation 30: The Microbiology of Yogurt — yogurt production and examination of the fermenting organisms, connected back to the Unit 2 fermentation tests and to lactic acid as a self-limiting preservative.
- Food intoxication versus infection case sort: students receive four case reports with onset-time distributions and must classify each and justify the classification from the incubation data alone before any laboratory result is revealed.
- Temperature abuse modeling: using the growth curve and generation time work from Unit 2, students compute the population reached in a food held at 25 °C for varying intervals and identify the point at which a hold time becomes unsafe (MP.2, HS-LS2-4).
- Investigation 29: Nitrogen Fixation by Bacteria — legumes inoculated and grown from seeds planted several weeks earlier, with root nodules examined and Gram stains prepared from nodule material. Seeds are planted during Unit 4 so that the plants are ready when the unit begins.
- Carbon and nitrogen cycle modeling: students build a matter-conserving model of each cycle, then test it by tracing a labeled nitrogen atom through the full cycle and confirming that it is neither created nor destroyed (HS-LS2-5, HS-LS2-4).
- Decomposition investigation: comparative decomposition rates under aerobic and anaerobic conditions, connected explicitly to composting and to landfill gas generation (HS-LS2-3).
- Investigation 27: Pipetting Technique and Serial Dilution — deliberate practice with dye solutions before any culture is diluted, so that arithmetic and technique errors are separated from biological results.
- Serial dilution problem set and error analysis: students work dilution problems, then diagnose four worked solutions containing characteristic errors — plate outside the countable range, dilution factor inverted, wrong volume plated, colonies counted on a confluent plate.
- Investigation 28: Counting Microbes Using the Pour Plate Technique and Serial Dilution — run as a municipal water quality

investigation. Each laboratory team processes one dilution level and the class pools results into a single determination, which requires teams to trust and audit one another's technique (9.4.12.CT.2).

- Coliform indicator reasoning: students are asked why the utility tests for coliforms rather than for a named pathogen, and must construct the public health and practical argument themselves before it is explained.
- Wastewater treatment plant analysis: students trace a system schematic, identify where microorganisms do the work, and evaluate performance data from influent and effluent samples against permit limits (8.2.12.ETW.2).
- Bioremediation design task: students propose a microbial approach to a local contamination scenario — a fuel spill, a nutrient-loaded pond, or a legacy industrial site — specify criteria and constraints, evaluate at least two alternatives, and refine their proposal after peer critique (HS-LS2-7, HS-ETS1-3, 8.2.12.ETW.3).
- Climate change connection: students analyze the role of methanogens and of thawing permafrost microbial communities in greenhouse gas flux, then collaboratively evaluate several proposed mitigation approaches and account for why political, economic, and cultural factors make some more workable than others (9.4.12.GCA.1; Climate Change).
- Industrial microbiology survey and bioethics seminar: students catalog microbially derived products in their own homes, then debate the governance of engineered organisms — who decides, who bears the risk, and who captures the benefit (8.2.12.EC.1 reinforced).
- Fermented foods of the world: students research a traditional fermented food from a culture other than their own, identify the organisms responsible, and explain the preservation chemistry, surfacing how microbial technology developed independently across cultures long before microbiology existed as a science (DEI; Global and Cultural Awareness; Asian American and Pacific Islander contributions to fermentation science and food traditions).
- Differentiation: dilution arithmetic supported with a fill-in dilution ladder for students who need it and open computation for those who do not; wastewater data provided in simplified and full versions; bioremediation task offered as a guided template or an open design brief; extension requiring students to compute a most probable number from a multiple-tube result.

Assessment Evidence

Formative Assessments:

- Preservation method to growth-requirement matching task.
- Food infection versus intoxication classification exit tickets using onset-time distributions.
- Temperature abuse computation problems with a written safety conclusion.
- Nitrogen cycle atom-tracing check for matter conservation.
- Serial dilution problem sets, including the four-error diagnostic set.

- Pipetting technique check with dye solutions, scored for volume accuracy before culture work is permitted.
- Countable-range judgment practice: students are shown twelve plate images and decide which are countable, which are too crowded, and which are too sparse.
- CFU/mL computation quick-checks with dilution factors supplied and then withheld.
- Coliform reasoning quick-write completed before instruction on indicator organisms.
- Wastewater schematic annotation identifying where microbial work occurs.
- Bioremediation proposal peer critique using a criteria-and-constraints checklist.

Summative Assessments:

- Food Microbiology Test: spoilage economics, preservation methods and their mechanisms, factors affecting growth in food, food infection versus intoxication, and a temperature-abuse computation with a written safety recommendation.
- Water Quality Laboratory Report: serial dilution and pour plate data, CFU/mL computation with the dilution factor and countable range shown, comparison against a stated standard, a conclusion about potability, and a required uncertainty section. This is the principal quantitative summative of the year.
- Nitrogen Fixation Investigation Report: nodule observations, Gram stain results, and an explanation of the symbiosis and its agricultural significance.
- Carbon and Nitrogen Cycle Model with written justification, assessed for matter conservation and for correct placement of microbial steps.
- Bioremediation Design Proposal: problem definition, criteria and constraints, evaluation of alternatives, recommended solution, and a revision log documenting refinement after peer critique. This proposal is the sole summative measure of the applied and industrial microbiology content; a separate end-of-unit test on that content is deliberately omitted to hold the unit to 15 instructional periods, and the material is assessed again on the final performance assessment.

Common Benchmark Assessments:

- Water Quality Quantitative Benchmark: a common serial dilution and plate count computation set administered across all sections, assessing the dilution arithmetic and countable-range reasoning that the final performance assessment requires.

- Final Performance Assessment "Township Water and Food Safety Investigation" Cumulative across the year with emphasis on Units 3 through 5. Students assume the role of a public health or environmental microbiologist, compute counts from serial dilution data, construct and interpret an epidemic curve, produce a CER explanation identifying the most probable vehicle and agent, distinguish food infection from intoxication using onset data, recommend next steps evaluated against criteria and constraints, and analyze sources of error. Scored with the common seven-trait performance rubric used since the diagnostic pre-assessment in Unit 1.

Alternative Assessments:

- Oral defense of the water quality determination with the computation shown and explained aloud, substituted for the written report.
- Annotated physical or digital cycle model with recorded narration, substituted for the written cycle justification.
- Bioremediation proposal delivered as a pitch presentation to a simulated township environmental commission rather than as a written document.
- Fermented foods research presented as a demonstration, recipe brief with microbiology annotations, or family-interview narrative, student's choice.
- Guided computation packet with the dilution ladder pre-structured, for students whose IEP or 504 plan identifies a mathematics disability, with the interpretive reasoning assessed at full weight.

Core Instructional & Supplemental Materials

- Van Hoeck, Kathy. Microbiology—Laboratory Activities. Flinn Scientific. Investigations 27–30.
- Yogurt with live cultures and milk for Investigation 30; soil samples; store-purchased food samples for spoilage and preservation comparison.
- Serial dilution supplies: sterile 0.9% saline, disposable pipettes and droppers, sterile screw-cap test tubes, graduated cylinders, food coloring or dye for pipetting practice, plate count or nutrient agar, sterile Petri dishes.
- Nitrogen fixation supplies: legume seeds (clover, bean, or pea) and Rhizobium inoculant, planting containers and soil, glass slides and Gram stain kit. Seeds must be planted approximately four weeks before the investigation, during Unit 4.

- Water samples: tap, pond or stream, and a deliberately contaminated laboratory sample. All environmental water samples handled as BSL-1 with no attempt at pathogen isolation or identification.
- Reference standards and public data: U.S. EPA National Primary Drinking Water Regulations (Total Coliform Rule) and heterotrophic plate count advisory levels; NJDEP surface water quality monitoring data; a local wastewater treatment plant schematic and publicly reported effluent data.
- USDA and FDA food safety resources: FoodKeeper, the Bad Bug Book (teacher reference), and HACCP overview materials.
- Case reports with onset-time distributions for the food infection versus intoxication sort (teacher-generated from published outbreak summaries).
- Seven-trait CER performance rubric and CER response frame (course-wide).

Accommodations and Modifications: Students with Disabilities, English Language Learners, Students at Risk of Failure, Students with 504s, Gifted & Talented Students

Specific Strategies and Practices that Support Students with Disabilities: Students receiving Special Education programming have specific goals and objectives, as well as accommodations and modifications outlined within their Individualized Education Plans (IEP) due to an identified disability and/or diagnosis. In addition to exposure to the general education curriculum, the instruction is differentiated based upon the student's needs. The IEP acts as a supplemental curriculum guide inclusive of instructional strategies that support each learner.

Unit-specific strategies: Dilution arithmetic supported with a pre-structured dilution ladder in which each step's volumes are labeled and only the dilution factor and final computation are completed by the student, so that the interpretive reasoning is assessed rather than the arithmetic sequencing. Pipetting practiced with dye until volume accuracy is demonstrated, with no culture handling until then and no time limit on reaching that point. Cycle models built from pre-cut manipulable components

rather than drawn from scratch. Bioremediation proposal completed against a sectioned template with each section conferenced separately.

Specific Strategies and Practices that Support English Language Learners: English language learner (ELL) is a national-origin-minority student who is limited-English-proficient. This term is often preferred over limited-English-proficient (LEP) as it highlights accomplishments rather than deficits.

Unit-specific strategies: Dilution and plate count vocabulary taught as a small closed set with a diagram for each term, since the quantitative reasoning in this unit is accessible well before the English terminology is. Regulatory standard documents provided in an excerpted plain-language version alongside the original. Fermented foods research explicitly invited on a food from the student's own family or culture, using home-language sources, which positions the student as the class expert. Numerical work assessed independently of written explanation so that computational competence is credited even where the written conclusion is still developing.

Students at Risk of Failure — unit-specific strategies: The water quality investigation structured so that each student's contribution is a discrete, achievable dilution level whose completion the group depends on, which raises accountability without raising individual load. Dilution problem sets assigned in short daily sets rather than as one large packet. Immediate feedback on every computation set, returned the same period. Final assessment review sessions scheduled during the school day rather than only after school. Credit recovery for missing work from earlier marking periods explicitly mapped and scheduled before the final assessment window closes.

Students with 504 Plans: Teachers are responsible for implementing designated services and strategies identified on a student's 504 Plan. 504 plans are formal plans that schools develop to give kids the support they need and cover any condition that limits daily activities in a major way. Students' accommodations are outlined in their individual 504 plan.

Unit-specific strategies: Extended time and a calculator permitted on all quantitative work, with the countable-range and dilution-factor reasoning assessed rather than arithmetic speed. Seated station with all dilution materials within reach. Plate counting available from projected or printed high-resolution images for students with visual impairment or fine-focus difficulty. Environmental water and soil sample handling modified for students with documented immunocompromise, with the digital data set substituted at full credit. Documented breaks during the extended final performance assessment period.

Specific Strategies and Practices that Support Gifted & Talented Students: It is critical that all teachers are able to recognize a high-ability student who may need more depth and complexity in instruction.

Unit-specific strategies: Students compute a most probable number from a multiple-tube fermentation result and compare it to their pour plate estimate, arguing which method is more appropriate under stated conditions. Extension analyzing real NJDEP monitoring data for a local water body across multiple years and identifying a trend with a proposed explanation. Bioremediation

proposals developed to a level suitable for presentation to an actual township environmental commission, with a cost estimate. Students design the dilution error-diagnostic set used by the rest of the class.

New Jersey Student Learning Standards - Science

Science

Scientific and technological advances have proliferated and now permeate most aspects of life in the 21st century. It is increasingly important that all members of our society develop an understanding of scientific and engineering concepts and processes. Learning how to construct scientific explanations and how to design evidence-based solutions provides students with tools to think critically about personal and societal issues and needs. Students can then contribute meaningfully to decision-making processes, such as discussions about climate change, new approaches to health care, and innovative solutions to local and global problems.

Three Dimensions of NJSLS Science

Performance Expectations (PE) are student learning standards devised with the three dimensions or components described below. For detailed information regarding the research and design behind the standards click here.

Disciplinary Core Ideas (DCI)

The fundamental ideas that are necessary for understanding a given science discipline. The core ideas all have broad importance within or across science or engineering disciplines, provide a key tool for understanding or investigating complex ideas and solving problems, relate to societal or personal concerns, and can be taught over multiple grade levels at progressive levels of depth and complexity.

- Disciplinary Core Ideas in Physical Science (PS)
- Disciplinary Core Ideas in Life Science (LS)
- Disciplinary Core Ideas in Earth and Space Science (ESS)
- Disciplinary Core Ideas in Engineering, Technology, and the Application of Science (ETS)

Science and Engineering Practices (SEP)

The practices are what students DO to make sense of phenomena. They are both a set of skills and a set of knowledge to be internalized. The SEPs reflect the major practices that scientists and engineers use to investigate the world and design and build systems.

Crosscutting Concepts (CCC)

These are concepts that hold true across the natural and engineered world. Students can use them to make connections across seemingly disparate disciplines or situations, connect new learning to prior experiences, and more deeply engage with material across the other dimensions. The NGSS requires that students explicitly use their understanding of the CCCs to make sense of phenomena or solve problems.

Science and Engineering Practices (SEP)	**Crosscutting Concepts (CCC)**
• Asking Questions and Defining Problems • Planning and Carrying Out Investigations • Analyzing and Interpreting Data • Developing and Using Models • Constructing Explanations and Designing Solutions • Engaging in Argument from Evidence • Using Mathematics and Computational Thinking • Obtaining, Evaluating, and Communicating Information	• Patterns • Cause and Effect: Mechanism and Explanation • Scale, Proportion, and Quantity • Systems and System Models • Energy and Matter • Structure and Function • Stability and Change