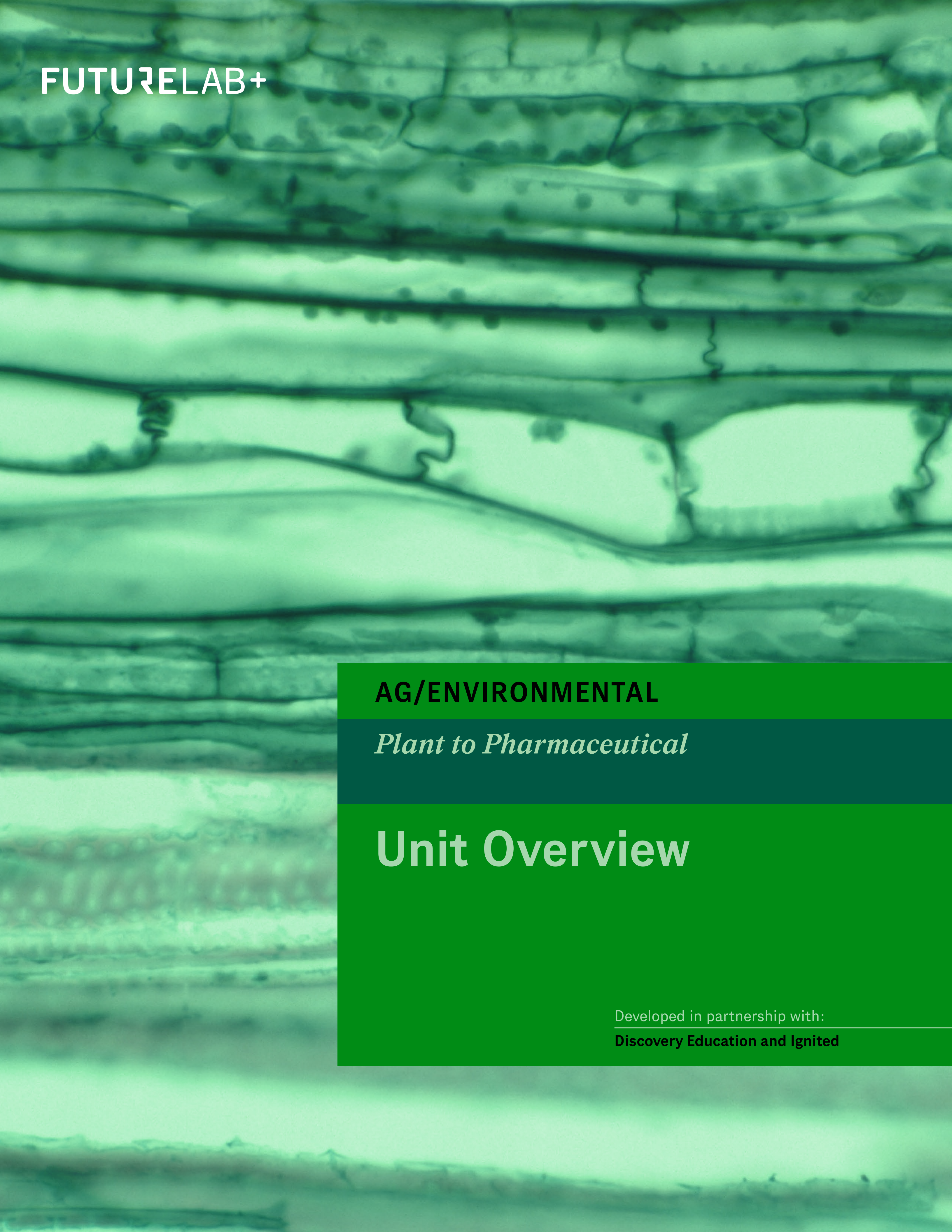


FUTURELAB+

AG/ENVIRONMENTAL

Plant to Pharmaceutical

Unit Overview

Developed in partnership with:

Discovery Education and Ignited

AG/ENVIRONMENTAL / PLANT TO PHARMACEUTICAL

Unit Overview

OVERVIEW

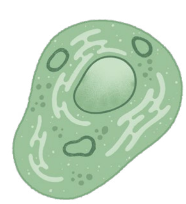
In this unit, students will explore how plant compounds are identified, isolated, and manufactured to treat disease. Students will create a biodiversity map to analyze where plants with bioactive properties might be located. They will discuss ethical questions arising during drug discovery around conservation and intellectual property, with an understanding of Indigenous Traditional Ecological Knowledge (TEK). Using evolutionary analysis, students will hypothesize relationships and medicinal properties of botanical specimens. Next, students will utilize an assay to identify one example of bioactivity in plants: antibiotic activity. Students will identify a bioactive plant compound and the condition treated by that compound using research, then collaborate to model a plant-based medicine, identify a patient population, and a plan to scale and manufacture the medicine. Students will evaluate their classmates' plant-based medicine products for iteration and improvement. For their final project, students will work as part of a pharmaceutical team that has developed a new drug derived from a plant with medicinal properties, before developing a sales pitch with a molecular model, communication plan, and financial analysis.

FINAL PROJECT PRODUCT

Pharmaceutical Sales Pitch

STUDENT-FACING UNIT TASK

You will take the role of a member of a pharmaceutical team seeking to develop a new drug derived from a plant with medicinal properties. Your team will share its molecular model showing how the compound acts to treat a condition, manufacturing plan, and pitch for why this drug is useful. You will share your work with community members in a showcase to celebrate what you have done over the unit, connecting your personal growth to potential careers including roles in communications, product and supply chain management, and biochemistry. You will analyze and provide feedback on the contributions of other people on your team, and the work products of other teams. Lastly, you will explicitly connect your work developing a plant-based medicine product to prior learning on biodiversity, ethical collaboration, botanical collections, Indigenous Traditional Ecological Knowledge (TEK), and bioactivity.



Lesson 1: Biodiversity on Earth

DRIVING QUESTION

How do scientists use mapping tools to investigate the relationships between diverse human stakeholders, their local ecosystems, and potential sources of plant-based medicine?

Student Objectives and CTE Standards	Connections to Careers and the Product Life Cycle	Lesson Materials	Lesson Overview	Phenomena and Connection to the Unit Storyline
Analyze the role of biodiversity in human health. **Identify** factors influencing the local and global distribution of biodiversity and observe changes in habitat quality over time. **Apply** a model of analysis to a biodiversity hotspot. **Categorize** the challenges that exist between different stakeholders in making conservation plans for diverse ecosystems. **Create** a visual model of biodiversity resource conflict. **CTE:** A2.4, A5.1, A7.1, 5.3, 5.4	Students explore careers as **climate scientists** and **medical anthropologists**. In this lesson, students will explore the **discovery** phase of drug development, learning about scientific tools used to document biodiversity. Biodiversity research is foundational to the drug discovery process, as documenting novel plant species is the first step toward identifying plants that might be used as the source of novel medicinal compounds. Given the myriad threats ecosystems face due to human land use, conservation and collaboration are essential to protecting these vital resources for future generations to discover new plant compounds.	Student Guide Location of Plants used as Medicine Map What Does Biodiversity Mean for Human Health? Capture Sheet Time Lapse Observation and Inference Capture Sheet Case Study Capture Sheet Student Hotspot Capture Sheet Extension Option Capture Sheet: Primary Source Material on Biodiversity Hotspots and Threats Google My Maps Student Instructions Computer with internet access Google My Maps Presentation Capture Sheet Gallery Walk Option Student Capture Sheet	In this lesson, students will investigate biodiversity challenges and conservation opportunities in biodiversity hotspots. Students will investigate a particular biodiversity challenge and display their findings using a map. This will allow students to demonstrate awareness of the needs of diverse stakeholder groups, ranging from Indigenous communities to biotechnology researchers.	The history of medicine and pharmaceuticals is based on what we have learned from the natural world in rich, biodiversity hotspots. Preserving biodiversity throughout our planet is essential for life on Earth, and is heavily impacted by human activity. Regions rich in biodiversity present complex challenges among stakeholder groups with regards to accessing natural resources, land use, cultural systems, and environmental protection and conservation.

Lesson 2: Ethical Collaboration

DRIVING QUESTION

What are the best practices for ethical collaboration between Indigenous communities and biotechnology researchers when developing new intellectual property during drug discovery?

Student Objectives and CTE Standards	Connections to Careers and the Product Life Cycle	Lesson Materials	Lesson Overview	Phenomena and Connection to the Unit Storyline
Identify various lenses of stakeholders involved in identifying plant resources for plant-based remedies and connect to careers. **Apply** understanding of IP regulations for ethical collaboration to case studies and evaluate actions using stakeholder perspectives. **Create** a classroom community that supports critical conversations surrounding complex issues that have no clear outcome. **Develop** recommendations for biotechnology companies to ethically collaborate with Indigenous communities and local governments. **CTE:** 9.5, A1.5, A2.4, A7.3	Students will explore careers as **ethnobotanists** and **corporate counsels**. During the **discovery** phase of the product development life cycle, researchers are challenged to narrow their focus to the most promising potential drug targets. One strategy is to partner with Indigenous communities. This facilitates the discovery of effective medicinal compounds because of the deep cultural knowledge and experience that Indigenous communities have cultivated surrounding medicinal plants in their local environment.	Student Guide History of Aspirin Capture Sheet History of Salicylic Acid to Aspirin Timeline Key Events Cards "Who Owns That?" Capture Sheet Stakeholder Perspective Profile Cards Case Study Capture Sheet Extension Option: Case Study Table for Primary Sources Stakeholder Case Study Jigsaw Information Capture Sheet Philosophical Chairs Capture Sheet Nagoya Protocol Article Excerpts Sticky notes (Optional for Gallery Walk) Best Practices for Ethical Collaboration Capture Sheet Materials to create posters or whiteboard and markers Computer with internet access	In this lesson, students will explore a case study jigsaw to illuminate patterns in stakeholder interests and concerns. Students will participate in a philosophical chairs discussion on the ethics of bioprospecting in regions of biodiversity and the concerns it raises in terms of ethical collaboration with Indigenous communities. Students will create a document of best practices for benefits sharing that will form a cornerstone of the final drug development project.	Indigenous communities have looked to plants for herbal remedies for centuries using deep Traditional Ecological Knowledge. Western science and medicine have relied on Indigenous knowledge about plants and plant properties. Ethical collaboration between Indigenous communities and outside groups requires acknowledgment of and compensation for intellectual property, and respect for diverse cultural beliefs.

Lesson 3: Botanical Collections and iNaturalist

DRIVING QUESTION

How are botanical collections used by scientists to study the taxonomy, genetics, and distribution of plants on Earth?

Student Objectives and CTE Standards	Connections to Careers and the Product Life Cycle	Lesson Materials	Lesson Overview	Phenomena and Connection to the Unit Storyline
Apply methods of biodiversity research in their immediate surroundings. **Collaborate** to design and complete an investigation of factors that drive plant diversity. **Evaluate** the advantages and shortcomings of their experimental design. **Connect** their methods and questions to the questions addressed by botanists and conservation biologists in global biodiversity hotspots. **CTE:** 5.4, A2.3, A8.8, A8.9	Students will explore careers as **museum botanists** and **field scientists**. This process connects the work of conservation and museum scientists to that of pharmaceutical researchers working in the drug **discovery** phase of the product development life cycle.	Student Guide Who are Museum Scientists? Capture Sheet Collecting and Preserving Plant Specimens Capture Sheet (Optional): iNaturalist App on Smartphones Newspaper Blotting paper (if possible) Cardboard Heavy books or pieces of wood for plant sample pressing Create a Plant Profile Capture Sheet Big poster paper or large whiteboard for each group Computer with internet access	In this lesson, students will explore the purpose of botanical collections and will have the opportunity to create a class botanical collection. This will connect students' knowledge of global patterns of biodiversity with distribution of biodiversity in their communities. Additionally, students will get an intimate perspective of how humans alter local biodiversity distribution through development and industry.	Students will apply the collection procedure of field botanists and conservation biologists by locating, identifying, and documenting local native flora. Students will construct a botanical collection and use that collection to create a hypothesis about the taxonomic relationships among different plant groups in their local environment. These two processes represent the foundational scientific process performed by botanists over generations to describe and document plant biodiversity, which is the first step in identifying plants that may contain medicinal compounds.

Lesson 4: The Role of Traditional Ecological Knowledge in Drug Development

DRIVING QUESTION

How can a community medicinal plant garden promote health and healing?

Student Objectives and CTE Standards	Connections to Careers and the Product Life Cycle	Lesson Materials	Lesson Overview	Phenomena and Connection to the Unit Storyline
Describe Indigenous Traditional Ecological Knowledge. **Design** a medicinal plant garden to address community needs. **Collaborate** to identify and narrow down specific medicinal plants for a patient population identified by the student group. **Provide** feedback to other student groups. **Deconstruct** a primary literature search and identify key ideas and concepts in a collaborative group. **CTE:** 2.5, A5.1, A9.4, A9.5	Students will explore careers as **traditional or naturopathic medicine practitioners** and **scientific illustrators**. During the drug target identification process, scientists often build on TEK to isolate particular compounds from plants with bioactive properties. By isolating the specific medicinal compound, scientists can start the process of preparing the medicine for clinical trials—a key part of product **development**.	Student Guide Tending Nature Reading Tending Nature Capture Sheet TEK Jigsaw Capture Sheet TEK Article Excerpts TEK Article Excerpts—Highlighted and Annotated Plant Profile Slide Medicinal Plant Profile Capture Sheet Common Medicinal Plant Menu Medicinal Community Garden Design Capture Sheet Template Plant Profile Gallery Walk Student Capture Sheet Computer with internet access Optional: paper, pens, dry erase board sticky notes	In this lesson, students will investigate approaches to preventive healthcare using whole plant medicines by researching bioactive plants, their Indigenous uses, and how they benefit health and well-being in addition to allopathic uses. They will learn about the Traditional Ecological Knowledge that has provided scientists and pharmaceutical companies with information on plants with compounds useful in promoting health and treating disease. They will have the opportunity to select a health issue prevalent in their lives or community, or a body system of particular interest, and design a plan for a medicinal garden.	Students will explore diverse models of disease, health, and treatment, and see models of their final product (a plant that could be used to treat disease) connected to its cultural context. Students' prior knowledge of stakeholders, intellectual property and ethical collaboration, and ecosystem structure (biotic and abiotic factors and their impact on biodiversity of plants) will aid them as they profile a particular medicinal plant and highlight the Indigenous cultural connections and ecological practices associated with that plant. This profile also provides a foundation for the Kirby Bauer assay by connecting students with the biological function of different plant-based medicines from a whole plant perspective. Finally, this lesson provides students an opportunity to connect with plants from an Indigenous way of knowing and a whole plant medicine perspective prior to exploring phytochemistry and plant-based compound medicines.

Lesson 5: Drug Discovery Using Plant Extracts

DRIVING QUESTION

How can we find bioactive compounds in nature?

Student Objectives and CTE Standards	Connections to Careers and the Product Life Cycle	Lesson Materials	Lesson Overview	Phenomena and Connection to the Unit Storyline
Explain how bioactive compounds from plants can be used as pharmaceuticals using scientific text. **Perform** a Kirby-Bauer assay to determine whether a plant sample has antibacterial properties using scientific protocols. **Analyze** results from a KirbyBauer assay to determine if a plant extract exhibits antibacterial properties using data collected from the lab. **Create** a testable question about a plant and discuss whether it is viable for continued research for use as a potential pharmaceutical using scientific text and data from the lab. **CTE:** A3.3, A4.2, A4.3, A8.1, A8.6, A8.7, A8.8, A9.4, A9.5	Students will explore careers as **microbiologists** and **pharmaceutical scientists**. Industry standards to focus on in-demand skills needed across the full product development life cycle—from molecule to medicine.	Documents: — Lab Preparation (for teacher) — Background Reading: Bioactive Compounds from Plants — Background Reading: Kirby-Bauer Assay — Vocabulary Tool Student Protocol, Part 1: Extract Bioactive Compounds Student Protocol, Part 2: Kirby-Bauer Assay, Student Guide, Materials, Reagents Lab Part 1: Extract Bioactive Compounds — Plant sample — Ampicillin — Extraction buffer Organic cornmeal (non-Bt-corn) Lab Part 2: Kirby-Bauer Assay — LB nutrient broth, sterilized — *E. coli* culture plates — LB agar plates Equipment and Consumables Lab Part 1: Extract Bioactive Compounds — 1.5 mL tubes — P200 micropipettes and tips — P1000 micropipettes and tips — Microtube rack — Waste container — Permanent marker — Pencil — Filter paper — Hole punch — Micropestles — Scissors or mortar and pestle (optional) Lab Part 2: Kirby-Bauer Assay — 1.5 mL tubes — P200 micropipettes and tips — P1000 micropipettes and tips — Microtube rack — Waste container with lysol or 10% bleach — Permanent marker — Inoculation loops — Sterile glass beads — Incubator — Strips of parafilm (optional)	In this lab, students will perform a Kirby-Bauer disk diffusion test, which is often used in drug discovery labs to determine if a particular plant extract or drug candidate has antibacterial activity. Students first collect a plant or plant product of interest and extract possible bioactive compounds from it. This plant extract is then soaked onto disks that are placed on LB agar plates spread with *E. coli* bacteria. Students then look for the presence or absence of bacterial growth around the disks and use these data to make a claim about whether or not the tested plant has antibiotic properties. Finally, students complete further independent research about the medicinal properties of their plant, and consider whether it is viable for continued research for use as a potential pharmaceutical.	This lab provides a hands-on example of how scientists can test plants for beneficial properties such as being antimicrobial. Students will also engage in research about their plant of choice to develop a fuller understanding of its bioactive compounds and historical and cultural uses.

Lesson 6: Plant and Disease

DRIVING QUESTION

How are plant-based medicines designed for a specific patient population?

Student Objectives and CTE Standards	Connections to Careers and the Product Life Cycle	Lesson Materials	Lesson Overview	Phenomena and Connection to the Unit Storyline
Identify a disease target and plant compound. **Build** connections between the product life cycle and career pathways. **Analyze** personal and collective strengths and areas for growth. **Apply** critical reading strategies for analyzing primary source information efficiently. **CTE:** A2.6, A4.5, A7.3, A7.6, A9.4, A9.5	Students will explore careers as **communications professionals**, **product and supply chain management professionals**, and **biochemists**. This lesson asks students to join a Project Team at a simulated Biotech Firm and to create a pitch on which they receive feedback from other Project Teams to identify a potential plant-based medicine. This provides an opportunity for each Project Team to give and receive feedback from peers and from the Project Team Lead (teacher), much as the Project Team Lead would provide a "go/no go" decision on a drug in the **discovery** phase of the product life cycle.	Student Guide Common Medicinal Plant Menu Plant Medicine Menu of Options Capture Sheet How are plant-based medicines designed for a specific patient population? Medicinal Plant Profile Capture Sheet Career Exploration Capture Sheet Career Profiles Career Role Profile Capture Sheet Drug Development Application Student Strengths and Areas of Growth Reflection Capture Sheet Project Team Collaboration Agreement Capture Sheet Individual Role Application for Project Team Construction Preliminary Background Research Capture Sheet Gallery Walk Capture Sheet	In this lesson, students will research plant drug candidates and explore compounds for drug development. They will learn about the mechanism of action connected to a plant compound they have chosen, and how it treats disease. They will begin to build a patient profile for their drug and think about what is necessary for mass production.	How do particular plant compounds address and treat a specific condition? How do drug developers determine who could benefit from their medicines? Students will identify a plant compound of interest and research how it interacts with the body on a cellular level, and begin defining a potential patient population. Students will gain exposure to biotechnology career roles in a simulated Biotech Firm, based on interests and personal growth goals, by assuming a Project Team position as they develop a plant-based medicine to treat a disease or symptoms of various diseases. The necessary skills in various stages of product development will be demonstrated by students throughout the process, while collaboration and communication will be emphasized for various group levels: role, sub, and larger group.

Lesson 7: Plant Medicine Product Development

DRIVING QUESTION

How do individuals collaborate on Project Teams to create a plant-based medicine, identify a patient population, and plan to scale and manufacture that medicine?

Student Objectives and CTE Standards	Connections to Careers and the Product Life Cycle	Lesson Materials	Lesson Overview	Phenomena and Connection to the Unit Storyline
Design a molecular model for how their plant molecule interacts with cells. **Analyze** whether a sustainable farming/purification approach or an organic/biologic synthesis approach makes more financial and environmental sense. **Develop** a marketing and communication plan. **Identify** a specific patient population for which the plant medicine is relevant. **CTE:** 5.3, 5.4, 5.6, 9.2, A2.6, A4.5, A7.3, A7.6, A9.4, A9.5, A9.7	Students will explore careers as **corporate relations professionals**, **product and supply management professionals**, and **biochemists**. This lesson asks students to work as a Project Team at a simulated Biotech Firm, and to create learning artifacts that mimic products that would be produced by professionals working in diverse roles. Students on the Communications Team will focus on defining their patient population and format for their final pitch. Students on the Finance Team will create a Benefits Sharing Agreement to honor the intellectual contributions of team members who were essential to the **discovery** phase of the product life cycle. The Molecular Modeling Team will analyze how the plant-based compound alters cell function. Scaffolded internal team feedback cycles will allow students to experience the key role of cross functional teams throughout the full product life cycle.	Construction Materials for Molecular Model: — Cardboard — Modeling clay — 3D printer (if available) — Popsicle sticks — Ribbon — Pipe cleaners — Beads — Toothpicks — Paper (many colors) — Paint Student Guide Project Team Progress Check Capture Sheet Molecular Modeling Team Day 1: Find a Protein and Medicine Model Using Molview Capture Sheet Molecular Modeling Team Day 2: Use a Model to Communicate Capture Sheet Molecular Modeling Team Days 3 and 4: Build Time Capture Sheet Molecular Modeling Team Day 5: Create a Science Guide Capture Sheet Communications Strategy Team Day 1: Identify Your Team's Patient Population Capture Sheet Communications Strategy Team Day 2: Identify the Audience for Your Communications Plan Capture Sheet Communications Strategy Team Day 3: Outline Communication Strategy Capture Sheet Communications Strategy Team Days 4 and 5: Create a Draft of the Communications Product Capture Sheet Financial Analysis Scaling Team Day 1: Values Discussion and Draft Benefit Sharing Plan Capture Sheet Financial Analysis Scaling Team Day 2: Question Selection and Research Capture Sheet Financial Scaling Analysis Team Day 3: Financial Analysis Introduction Capture Sheet Financial Scaling Analysis Team Day 3: Decision Matrix Financial Analysis Team Day 4: Complete Draft Quantitative Analysis Capture Sheet Financial Analysis Team Day 5: Check In and Seek Feedback Capture Sheet	In this lesson, students will collaborate on three project Sub-Teams: The Molecular Modeling Team will build a two- or three dimensional model, demonstrating how a plant compound interacts with cell structures to treat a particular human disease or condition. The Communications Strategy Team will identify a patient population and develop a communication strategy for the plant-based medicine, describing the target audience and communication product format. The Finance Team will create a Benefits Sharing Agreement honoring the contributions of key stakeholders to the discovery of the plant-based medicine and will analyze the mode of manufacturing that will best get the plant compound to market at scale.	As employees of a simulated Biotech Firm, students will collaborate to determine the patient population who would benefit from a plant based medicine, and an audience to which to market it. Students will research and model the effects of a bioactive plant compound on the human body to communicate the mechanism of action with the target audience. Different methods of drug production will be evaluated to determine the most beneficial production plan for all stakeholder groups.

Lesson 8: Product Development: Collaboration, Feedback, and Revisions

DRIVING QUESTION

How do teams communicate to evaluate and improve a product?

Student Objectives and CTE Standards	Connections to Careers and the Product Life Cycle	Lesson Materials	Lesson Overview	Phenomena and Connection to the Unit Storyline
Refine their products from Lesson 7. **Communicate** the rationale behind the design, finance, and communications strategy. **Collaborate** across teams to give and receive feedback using the Class Ethics Framework document (from Lesson 2). **Prepare** for the showcase in Lesson 9. **CTE:** 7.3, 7.4, 7.5, 9.2, A2.6	Students will explore careers as **communications professionals**, **product and supply chain management professionals**, and **biochemists**. As a medicinal plant product moves from **discovery** to **development** to **manufacturing**, there are internal and external approval processes that occur to verify that the product is safe and efficacious. All of these processes revolve around clear communication, review, and feedback, and lead to more effective medicines that are hopefully available to the patients that need them.	Student Guide Project Team Progress Check Capture Sheet Peer Feedback Capture Sheet Construction materials for molecular model — Cardboard — Modeling clay — 3D printer (if available) — Popsicle sticks — Ribbon — Pipe cleaners — Beads — Toothpicks — Paper (many colors) — Paint	In this lesson, students will provide kind, specific, and helpful feedback to classmates within and across Project Team career roles. Students will integrate received feedback into revisions of their project products, and prepare to present their plant-based medicine to their audience. Opportunities will be provided for structured “project tuning” protocols, supporting students to interact constructively with peers during the feedback process.	As biotech development firms move a particular product through the product life cycle, they must review and revise products in order to meet regulatory guidelines. The feedback process is essential to determine and incorporate necessary changes to create a successful product. Teams collaborate with colleagues in different career roles to gain a better understanding of where products need improved depth, clarity, and communication of information.

Lesson 9: Product Showcase

DRIVING QUESTION

What supporting evidence do biotech companies use to determine which drugs to bring to market?

Student Objectives and CTE Standards	Connections to Careers and the Product Life Cycle	Lesson Materials	Lesson Overview	Phenomena and Connection to the Unit Storyline
Describe their individual growth, strengths, and content knowledge for the Project and for the unit as a whole. **Communicate** their pitch to the class, clearly explaining their financial scaling plan, molecular model, and details about their medicine's patient population. **Analyze** and provide feedback on the contributions of other people on their team, and the work products of other project teams. **Reflect** and celebrate work and collaboration throughout the project. **CTE:** 2.5, 9.5, 11.4, A2.6, A4.5, A7.3, A7.6, A9.4	Students will explore careers as **communications professionals**, **product and supply chain management professionals**, and **biochemists**. Students are completing an external communication that might be used in sharing the news of a plant-based medicine with a specific audience. In general, this type of communication follows many years of clinical trials and FDA approval, which is not included in this lesson. However, including authentic communication toward a particular target audience is an essential part of the **commercialization** phase of the product life cycle and this lesson provides the opportunity for students to experience this piece.	Student Guide Project Team Member Review Capture Sheet Peer Feedback Capture Sheet Student Final Performance Review Capture Sheet Individual Reflection Capture Sheet Posters Sticky notes	In this lesson, students will also have the opportunity to share their work with adult community members in a showcase (teacher choice here). This week is a celebration of the learning that students have done over the unit, connecting their personal growth to potential careers including roles in communications, product and supply chain management, and biochemistry. Additionally, students will explicitly connect their work developing a plant-based medicine product to prior learning on biodiversity, ethical collaboration, botanical collections, Indigenous TEK, and bioactivity.	The work of many teams at a biotech firm goes into the pitch of a plant-based medicine as a result of the product life cycle. Strong collaborative efforts create a clear and focused pitch presentation to communicate the product to the target audience and public. Personal review and reflection are key aspects of successful collaboration when creating a product. Materials provided in this lesson will allow students to evaluate their growth in their career role. Reflection and synthesis of key ideas over the duration of the unit will allow students to explain the interconnectedness among human and non-human inhabitants on Earth, and the impacts of our actions on valuable genetic diversity for future generations.

Career and Technical Education (CTE) Standards

Anchor Standards

2.0 Communications
Acquire and accurately use Health Science and Medical Technology sector terminology and protocols at the career and college readiness level for communicating effectively in oral, written, and multimedia formats. (Direct alignment with LS 9–10, 11–12.6)

2.5
Communicate information and ideas effectively to multiple audiences using a variety of media and formats.

5.0 Responsibility and Flexibility
Conduct short, as well as more sustained, research to create alternative solutions to answer a question or solve a problem unique to the Health Science and Medical Technology sector using critical and creative thinking, logical reasoning, analysis, inquiry, and problem-solving techniques. (Direct alignment with WS 11-12.7)

5.3
Use systems thinking to analyze how various components interact with each other to produce outcomes in a complex work environment.

5.4
Interpret information and draw conclusions, based on the best analysis, to make informed decisions.

5.6
Read, interpret, and extract information from documents.

7.0 Responsibility and Flexibility
Initiate and participate in a range of collaborations demonstrating behaviors that reflect personal and professional responsibility, flexibility, and respect in the Health Science and Medical Technology sector workplace environment and community settings. (Direct alignment with SLS 9–10, 11–12.1)

7.3
Understand the need to adapt to changing and varied roles and responsibilities.

7.4
Practice time management and efficiency to fulfill responsibilities.

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Career and Technical Education (CTE) Standards

Anchor Standards

Continued

7.5
Apply high-quality techniques to product or presentation design and development.

9.0 Leadership and Teamwork
Work with peers to promote divergent and creative perspectives, effective leadership, group dynamics, team and individual decision making, benefits of workforce diversity, and conflict resolution as practiced in the Cal-HOSA career technical student organization. (Direct alignment with SLS 11-12.1b).

9.2
Identify the characteristics of successful teams, including leadership, cooperation, collaboration, and effective decision-making skills as applied in groups, teams, and career technical student organization activities.

9.5
Understand that the modern world is an international community and requires an expanded global view.

11.0 Demonstration and Application
Demonstrate and apply the knowledge and skills contained in the Health Science and Medical Technology anchor standards, pathway standards, and performance indicators in classroom, laboratory, and workplace settings and through the Cal-HOSA career technical student organization.

11.4
Employ entrepreneurial practices and behaviors appropriate to Health Science and Medical Technology sector opportunities.

Health Science and Medical Technology Standards

A1.0
Define and assess biotechnology and recognize the diverse applications and impact on society.

A1.5
Evaluate the impact of biotechnological applications on both developing and industrial societies, including legal and judicial practices.

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Career and Technical Education (CTE) Standards

Health Science and Medical Technology Standards

Continued

A2.0
Understand the ethical, moral, legal, and cultural issues related to the use of biotechnology research and product development.

A2.3
Understand the necessity for accurate documentation and record keeping.

A2.4
Understand the critical need for ethical policies and procedures for institutions engaged in biotechnology research and product development.

A2.6
Prepare a presentation comparing the benefits and harm that can be the result of biotechnology innovations in both the research and application phases and which course of action will result in the best outcomes.

A3.0
Demonstrate competencies in the fundamentals of molecular cell biology, including deoxyribonucleic acid (DNA) and proteins and standard techniques for their purification and manipulation.

A3.3
Employ standard techniques of DNA extraction, purification, restriction digests, bacterial cell culture, and agarose gel electrophoresis and document and evaluate results.

A4.0
Recognize basic concepts in cell biology and become familiar with the laboratory tools used for their analysis.

A4.2
Describe conditions that promote cell growth under aseptic conditions in the laboratory and workplace.

A4.3
Use various methods to monitor the growth of cell cultures.

A4.5
Discuss the structure and function of the macromolecules that compose cells, including carbohydrates, lipids, DNA, RNA, and protein molecules.

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Career and Technical Education (CTE) Standards

Health Science and Medical Technology Standards

Continued

A5.0
Integrate computer skills into program components.

A5.1
Use the internet and world wide web to collect and share scientific information.

A5.3
Compile labs (results, tables, graphs) in a legal, scientific notebook and/or an internet site or web page.

A7.0
Understand the function of regulatory agencies for the biotechnology industry and the lasting impact of routine laboratory and communication practices on product development and manufacturing.

A7.1
Identify agencies at the local, state, and federal levels.

A7.3
Describe intellectual property.

A7.6
Articulate issues of ethical concern, including plagiarism, copyrights, trademarks, and patents and use online data resources and searchable databases to investigate a copyright, trademark, or patent.

A8.0
Follow sustainable and safe practices with high regard for quality control.

A8.1
Follow written protocols and oral directions to perform a variety of laboratory and technical tasks.

A8.6
Properly and safely use and monitor a variety of scientific equipment, including pH meters, microscopes, spectrophotometers, pipettes, micropipettes, and balances.

A8.7
Determine which equipment is appropriate to use for a given task and the units of measurement used.

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Career and Technical Education (CTE) Standards

Health Science and Medical Technology Standards

Continued

A8.8
Perform specimen collection, label samples, and prepare samples for testing.

A8.9
Handle, transport, and store samples safely.

A9.0
Understand that manufacturing represents inter-connectedness between science and production.

A9.4
Cite examples of plant parts or extracts used as pharmaceuticals.

A9.5
Use the internet to find information about traditional pharmaceuticals, herbal remedies, and recombinant pharmaceuticals.

A9.7
Design a flowchart describing the steps for creating a new drug from hypothesis to distribution.

Third Party Evaluator Evidence/Findings

Completed by: American Institute of Research

Sponsored by Genentech, Futurelab+ brings together a coalition of partners to develop an innovative, modular, two-year biotechnology curriculum, including instructional materials, to expose students and educators to the breadth of education and career pathways across biotechnology. To increase adoption and access to such curricula in California and beyond, the modular curriculum was designed to align with the *California Career Technical Education (CTE) Model Curriculum Standards for Biotechnology*, meet at least one year of the *University of California science (D) subject requirement*, and incorporate some of the three-dimensional learning innovations of the *Next Generation Science Standards* (NGSS).

The two-year biotechnology curriculum provides four core units per year; each core unit has nine lessons and a lab that each take approximately one week to complete, or 9–10 weeks for the full unit. In total, the biotechnology curriculum has 72 lessons and eight labs that span two full instructional years. Because the Futurelab+ biotechnology curriculum is modular, teachers can select specific units and materials to design biotechnology courses that are relevant and appropriate for their students and teaching environment.

Unit 7: Plant to Pharmaceutical

Version Reviewed/ Date: May 3, 2022

California (CTE) Model Curriculum Standards for Biotechnology

Full Report

[Futurelab+… priority to meet California CTE Biotech Standards…] Evidence of which California CTE Biotechnology standards are addressed within the curriculum and where they are addressed is included in the *full report*.

University of California Science (D)

Full Report

Because teachers and schools can choose which portions of the curriculum to include in their final course designs, this *report series* provides evidence of where each unit meets specific criteria for the UC science (D) subject requirement and, when incorporated into a full year-long course, where the curriculum could meet at least one year of the UC science (D) subject requirement, contingent upon review and approval by UC. Subsequently, the evidence provided within the report can be used by teachers for submitting Futurelab+ course materials for UC science (D) subject approval.

The purpose of this report is to provide evidence for alignment of Unit 7 of the Futurelab+ Biotechnology Curriculum with the UC science (D) subject requirement. To help educators submit their final courses for UC science (D) subject review, the American Institutes for Research (AIR) also provides a sample unit and lab summaries, which follow the guidelines for writing a UC science (D) course (March 17, 2021).

Specifically, AIR reviewed each unit for evidence of the extent to which they meet the eight Course Content Guidelines for the UC science (D) subject requirement. This report provides specific examples to demonstrate where and how materials satisfy these criteria. Based on our review, we believe there is a strong body of evidence that will translate to Unit 7 meeting the UC science (D) subject matter requirement.

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Third Party Evaluator Evidence/Findings

Continued

Next Generation Science Standards (NGSS)

Full Report

As an organizational partner, the American Institutes for Research (AIR) provided external feedback on alignment to the three sets of standards to Futurelab+ curriculum developers during the formative period of the biotechnology curriculum. AIR is now providing external feedback and evidence on the final curriculum's alignment to each set of standards: CTE, UC science (D) subject requirement, and NGSS in a series of three reports. The eight reports in the NGSS series provide feedback on aspects of NGSS in a sample of the curriculum (one lesson from each unit). Developers selected Lesson 7 (Plant Medicine Product Development) from Unit 7 (Plant to Pharmaceutical) for this report.

Of note, because the primary design element of the curriculum was alignment to CTE, AIR used the NGSS Lesson Screener (not the Educators Evaluating the Quality of Instructional Products [EQuIP] Rubric) to identify aspects of the curriculum that incorporate NGSS. The EQuIP Rubric is typically used to determine whether a unit was designed for the NGSS. Because the curriculum was designed to align primarily to CTE standards, it was not expected that the curriculum would meet all NGSS criteria. Nevertheless, in their current form, the materials from Unit 7, Lesson 7, meet four lesson screener criteria and approach the remaining two lesson screener criteria. AIR created the approaching rating to indicate where a modification to materials would increase the rating to adequate. For more information, please see the *full report*.