

FUTURELAB+

AG/ENVIRONMENTAL

*Plant to Pharmaceutical*

# Student Guide

Developed in partnership with:

Discovery Education and Ignited

# In this Student Guide:

Print the **Teacher Section** → 

Print the **Student Section** → 

<b>01</b>	<b>For Teachers</b>	Page
<b>Answer Keys</b>		
	Lesson 1: Biodiversity on Earth	<b>1</b>
	Lesson 2: Ethical Collaboration	<b>2</b>
	Lesson 3: Botanical Collections and iNaturalist	<b>3</b>
	Lesson 4: The Role of Traditional Ecological Knowledge in Drug Development	<b>4</b>
	Lesson 5: Drug Discovery Using Plant Extracts	<b>5</b>

<b>02</b>	<b>Student Resources</b>	Page
	Lesson 1: Biodiversity on Earth	<b>1-2</b>
	Lesson 2: Ethical Collaboration	<b>3-4</b>
	Lesson 3: Botanical Collections and iNaturalist	<b>5-6</b>
	Lesson 4: The Role of Traditional Ecological Knowledge in Drug Development	<b>7-8</b>
	Lesson 5: Drug Discovery Using Plant Extracts	<b>9-10</b>
	Lessons 6-9: Project Team Process Journal	<b>11-12</b>

*This document is separated into two sections, For Teachers [T] and Student Resources [S], which can be printed independently.*

*Select the appropriate printer icon above to print either section in its entirety.*

*Follow the tips below in the Range field of your Print panel to print single pages or page ranges:*

Single Pages (use a comma): T3, T6

Page Range (use a hyphen): T3-T6

#### Cover Image

The Solanaceae plant family is rich in bioactive metabolites and has played an essential role in traditional medicine.

**Lesson 1: Biodiversity on Earth****ANSWER KEY****Do not share with students****Directions**

*For each question, provide the concepts, skills, and stakeholder communities we explored.*

Students will likely have only some of the below bullet points.

**1. How is biodiversity connected to human health?**

Biodiversity—the collection of all living things on the planet, from microbes to blue whales, is essential to human health because:

- Healthy local diets rely on high biodiversity levels
- Sixty percent of the world population uses traditional medicines, commonly plant-based, supplied by wild collection and cultivation

Human disturbance of native biodiversity is harmful to human health due to:

- Introduction of new and dangerous pathogens
- Loss of potential medicinal genes and chemicals due to extinction
- Negative impacts on climate and natural resources

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

Answers will vary. Possible answers may contain some of the following:

- Scientists use mapping tools to document relationships between humans and ecosystem components.
- They capture GPS data in the field and then construct maps to communicate spatial data.
- These maps can be the basis of policy and conservation decisions that protect plant-based medicines and other biodiversity resources for years to come.

**3. How do humans collaborate effectively to conserve biodiversity hotspots as sources of plant-based medicine in the face of habitat destruction and climate change?**

Industry groups, farmers/agricultural workers, Indigenous communities, and urban residents all have a stake in conserving local ecosystems. Effective conservation strategy considers:

- The needs of present and future generations
- The services provided by ecosystems
- The cultural and psychological importance (biophilia) of diverse, functioning ecosystems

Through community-building exercises that consider environmental and economic factors, local ecosystems can be managed in a way that is resilient to habitat destruction and climate change.

**4. How does preserving plant biodiversity conserve compounds and genes that may hold the key to treating disease?**

- Scientists estimate that much of the plant biodiversity on Earth is yet to be fully characterized and described.
- Each plant faces predation and other challenges, and has evolved over time due to different environmental pressures.
- These environmental pressures drive the development of compounds within the plants that serve a specific function for that species, but often have an additional medicinal roles for humans.

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**Lesson 2: Ethical Collaboration****ANSWER KEY****Do not share with students****Directions**

*For each question, provide the concepts, skills, and stakeholder communities we explored.*

Students will likely have only some of the below bullet points.

**1. What best practices need to be implemented for ethical collaboration between Indigenous communities and biotechnology researchers to best enable the discovery of intellectual property foundational to plant-based medicine?**

- Protecting biodiversity resources for the duration of the drug development process and beyond
- Obtaining prior informed consent in methods that appropriately includes Indigenous communities and local governments before accessing Traditional Ecological Knowledge and genetic resources
- Developing Benefit Sharing Agreements that are equitable to all groups and take into account non-monetary compensation such as: conservation efforts, acknowledging IP, and supporting local economies and livelihoods
- Observing protocols of Indigenous communities when accessing Traditional Ecological Knowledge and genetic resources

**2. How do we ethically acknowledge the role of Traditional Ecological Knowledge (TEK) in the development of intellectual property surrounding plant-based medicines?**

Biotechnology companies can look for ways to incorporate all stakeholder groups, such as Indigenous communities, with a history of knowledge about a medicinal plant into the drug development process by:

- Acknowledging IP
- Partnering in the production of genetic resources to share benefits when possible
- Supporting conservation

**Lesson 3: Botanical Collections and iNaturalist****ANSWER KEY****Do not share with students****Directions**

*For each question, provide the concepts, skills, and stakeholder communities we explored.*

Students will likely have only some of the below bullet points.

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

Botanical collections form a library of knowledge that allows scientists to study the past and present distribution of plant biodiversity on Earth.

Each specimen has a label that identifies its collection location and date of collection; which allows scientists to precisely identify where and when a plant was collected and archived.

Scientists utilize a diverse range of skills, from scientific illustration to taxonomy to molecular genomics, as they build modern botanical collections.

**2. How do scientists document plant biodiversity in their environments?**

Scientists first have to decide where they want to study a plant.

Generally, the field site is chosen based on the scientific question, on previous observations in botanical collections, or on knowledge of sites that have had little formal scientific research.

Scientists then make a plan for what types of plant species they want to document. They consider:

- Seasonality
- Previous plant observations
- Accessibility to the site
- Ecosystem types at the site
- Where the plant has been found previously if it is known to science

Scientists then photograph and collect whole plant and tissue samples.

- For DNA and RNA, this process might involve ultra cold storage (-90°C) to preserve the genetic material until returning to the lab.

**3. How does studying the taxonomic relationships of plants enable scientists to better identify potential plant medicines?**

These collections allow us to understand the evolutionary relationships among plant species and allow scientists to make hypotheses based on prior knowledge about which plants might have medicinal compounds, among other key plant characteristics.

**Lesson 4: The Role of Traditional Ecological Knowledge in Drug Development****ANSWER KEY****Do not share with students****Directions**

*For each question, provide the concepts, skills, and stakeholder communities we explored.*

Students will likely have only some of the below bullet points.

**1. How do different communities define disease and health? How are plant-based medicines used proactively for health?**

Non-Western communities often focus on the whole human (emotional, physical, spiritual) and the connection between that individual human and other components of the local environment and human community.

Indigenous communities have a health practice from the soil up. They work on preventing illness (in both humans and other living parts of the ecosystem) by building strong interpersonal relationships, managing the environment with future generations in mind, and cultivating a relationship with plants, animals, and physical aspects of the environment (water, soil, fire).

If a cut, or injury or illness occurs, the first round of treatment might include plant-based medicine and a special diet that is specific to that community and environment.

**2. How do specific Indigenous cultures view biodiversity?**

Many Indigenous cultures view biodiversity through a TEK way of thinking, which includes beliefs that:

- Humans are a part of their environment and do not live separate from it (i.e., all things are connected).
- Non-human entities are respected as individuals related to humans.

**3. How do we navigate differences between Indigenous and non-Indigenous views regarding natural resources?**

Indigenous views are “spatial” in thinking, and humans exist as part of the ecological system they live in:

- Humans should not “protect” (thus control) the environment as a steward.
- Nature and natural resources are not seen as wilderness, but an extension of “home.”
- TEK way of thinking integrates biology and chemistry, and shares ideologies with Western ecological sciences.

**4. How can we design a community medicinal plant garden to promote health and healing?**

A medicinal plant garden can incorporate:

- Species that promote general systemic health
- Species that purely focus on treating specific ailments
- Species that focus on treating ailments and promoting health for specific body systems (e.g., respiratory)

**Lesson 5: Drug Discovery Using Plant Extracts****ANSWER KEY****Do not share with students****Directions**

For each question, provide the concepts, skills, and stakeholder communities we explored.

Students will likely have only some of the below bullet points.

**1. How do we test for antibiotic properties of plants?**

Using a Kirby-Bauer assay (disc diffusion test), we can visualize whether and how much antibiotic activity a particular plant extract has against a specific microbe (e.g., *E. coli*).

**2. What gives plants their beneficial properties?**

- Over evolutionary time, plants have adapted to their environments.
- Plants are eaten by a wide variety of animal species and adapt to avoid herbivory.
- Plants face a wide range of pathogens and develop defenses in the face of these infections.

**3. How have plants been used to treat and prevent disease?**

Plants are used as medicines in Indigenous communities, cultures, and civilizations throughout human history.

- They are used as teas, tinctures, balms, essential oils, and in other whole plant medicine forms.
- More recently, pharmaceutical companies have isolated individual plant compounds that can then be delivered as pills, IV medications, or other formats to treat illnesses.

**4. How are new drugs discovered?**

New plant-based medicinal compounds can be identified by medical anthropologists in collaboration with Indigenous TEK practitioners.

Pharmaceutical scientists, biochemists, and microbiologists collaborate to investigate isolated plant compounds for bioactivity.

- Bioactivity includes:
  - Anticancer
  - Anti-inflammatory
  - Anti-diarrheal
  - Antimicrobial

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## Lesson 1: Biodiversity on Earth

### Directions

For each question, provide the concepts, skills, and stakeholder communities we explored.

**1. How is biodiversity connected to human health?**

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

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**3. How do humans collaborate effectively to conserve biodiversity hotspots as sources of plant-based medicine in the face of habitat destruction and climate change?**

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**4. How does preserving plant biodiversity conserve compounds and genes that may hold the key to treating disease?**

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## Lesson 1: Biodiversity on Earth

*Continued*

*Create a reflection (either written or visual) of how this lesson:*

- 1. Surprised you...*
- 2. Made you wonder about...*
- 3. Helped you reflect on your own life...*

**Surprised you...**

**Made you wonder about...**

**Helped you reflect on your own life...**

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## Lesson 2: Ethical Collaboration

### Directions

For each question, provide the concepts, skills, and stakeholder communities we explored.

- 1. What best practices need to be implemented for ethical collaboration between Indigenous communities and biotechnology researchers to best enable the discovery of intellectual property foundational to plant-based medicine?**

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- 2. How do we ethically acknowledge the role of Traditional Ecological Knowledge (TEK) in the development of intellectual property surrounding plant-based medicines?**

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## Lesson 2: Ethical Collaboration

*Continued*

*Create a reflection (either written or visual) of how this lesson:*

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Surprised you...	Made you wonder about...	Helped you reflect on your own life...

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## Lesson 3: Botanical Collections and iNaturalist

### Directions

For each question, provide the concepts, skills, and stakeholder communities we explored.

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

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**3. How does studying the taxonomic relationships of plants enable scientists to better identify potential plant medicines?**

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**2. How do scientists document plant biodiversity in their environments?**

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## Lesson 3: Botanical Collections and iNaturalist

*Continued*

*Create a reflection (either written or visual) of how this lesson:*

- 1. Surprised you...*
- 2. Made you wonder about...*
- 3. Helped you reflect on your own life...*

Surprised you...	Made you wonder about...	Helped you reflect on your own life...

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

### Directions

For each question, provide the concepts, skills, and stakeholder communities we explored.

**1. How do different communities define disease and health? How are plant-based medicines used proactively for health?**

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**2. How do specific Indigenous cultures view biodiversity?**

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**3. How do we navigate differences between Indigenous and non-Indigenous views regarding natural resources?**

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**4. How can we design a community medicinal plant garden to promote health and healing?**

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

*Continued*

*Create a reflection (either written or visual) of how this lesson:*

- 1. Surprised you...*
- 2. Made you wonder about...*
- 3. Helped you reflect on your own life...*

Surprised you...	Made you wonder about...	Helped you reflect on your own life...

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## Lesson 5: Drug Discovery Using Plant Extracts

### Directions

For each question, provide the concepts, skills, and stakeholder communities we explored.

#### 1. How do we test for antibiotic properties of plants?

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#### 2. What gives plants their beneficial properties?

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#### 3. How have plants been used to treat and prevent disease?

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#### 4. How are new drugs discovered?

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## Lesson 5: Drug Discovery Using Plant Extracts

*Continued*

*Create a reflection (either written or visual) of how this lesson:*

- 1. Surprised you...*
- 2. Made you wonder about...*
- 3. Helped you reflect on your own life...*

Surprised you...	Made you wonder about...	Helped you reflect on your own life...

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## Lessons 6–9: Project Team Process Journal

Project Phase		What solutions did our Project Team create?	What I contributed to the process: (highlight key career connections and soft and technical skills)	What challenges did our Project Team have?
<b>Discover</b>	<i>Modeling Team:</i> Identify a Plant-Based Medicine.			
	<i>Modeling Team:</i> Model how the plant-medicine compound impacts cells to treat disease.			
	<i>Modeling Team:</i> Describe how the plant-medicine treats symptoms or diseases.			
<b>Develop</b>	<i>Communications Team:</i> Identify and characterize a patient population for the plant medicine.			
	<i>Finance Team:</i> Create a Benefits Sharing Agreement for relevant stakeholders.			
	<i>Communications Team:</i> Consider how manufacturing strategies and communications plans can be used to increase access to medicine in diverse communities.			

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## Lessons 6–9: Project Team Process Journal

Continued

Project Phase		What solutions did our Project Team create?	What I contributed to the process: (highlight key career connections and soft and technical skills)	What challenges did our Project Team have?
<b>Manufacture</b>	<i>Finance Team:</i> Analyze different production scaling strategies.			
	<i>Communications Team:</i> Explain how your scaling strategy maximizes benefits for different stakeholder groups.			
	<i>Finance Team:</i> Explain how your scaling strategy minimizes environmental impacts and other external impacts.			
<b>Commercialize</b>	<i>Communications Team:</i> Identify an audience for communications strategy.			
	<i>Communications Team:</i> Justify your selected communications media format (i.e., written, visual, audio, video).			
	<i>Project Team:</i> Clearly explain to your audience the science of how the plant-medicine treats symptoms or disease.			
	<i>Project Team:</i> Describe how your Benefits Sharing Agreement and Scaling Plan increase access to your plant-based medicine to diverse patient populations.			