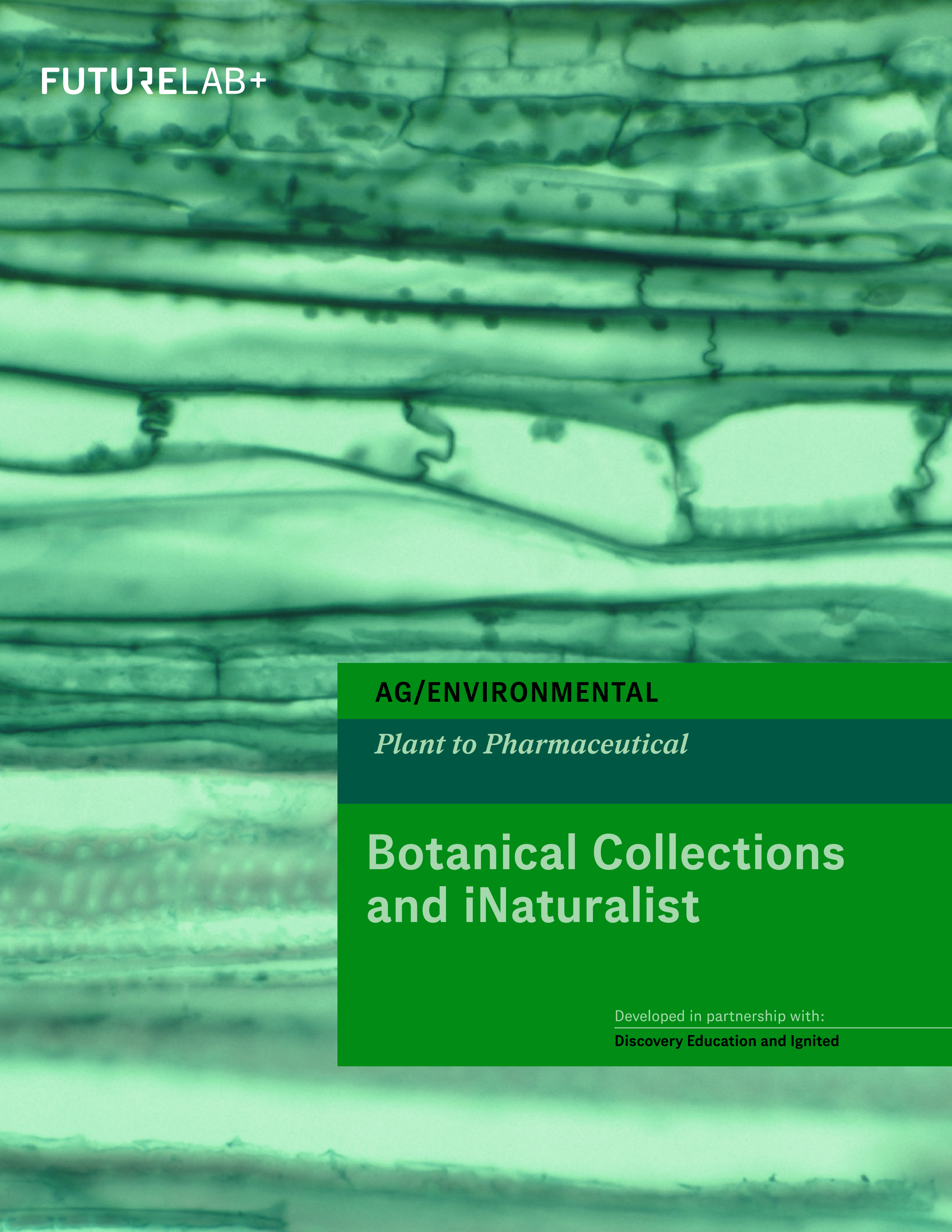


FUTURELAB+

AG/ENVIRONMENTAL

Plant to Pharmaceutical

Botanical Collections and iNaturalist

Developed in partnership with:
Discovery Education and Ignited

In this Lesson Plan:

Print the **Teacher Section** →

Print the **Student Section** →

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

A farmer harvesting ripe date palm.

—

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

AG/ENVIRONMENTAL / PLANT TO PHARMACEUTICAL

Botanical Collections and iNaturalist

ACTIVITY DURATION

Four class sessions
(45 minutes each)

DRIVING QUESTION

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

ESSENTIAL QUESTIONS

How do scientists document plant biodiversity in the environment?

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

OVERVIEW

Botanical collections are an essential tool for botanists and for phytochemists as they explore the functional uses of plants in their ecosystems and for human health. They allow scientists to document what plant species have lived in specific locations over time, and whether those species distributions are changing in response to habitat destruction or climate change. Additionally, plant collections allow scientists to make hypotheses about the course of evolutionary history and build a family (phylogenetic) tree of plants. This family tree additionally allows researchers to map functional traits and target searches for medicinal plants in a more strategic manner, given that related plants often share similar phytochemistry profiles.

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.

OBJECTIVES

Students will be able to:

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.

This is an image of the sun streaming through the forest.

Materials
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
Internet access

Pedagogical Framing

Instructional materials are designed to meet national education and industry standards to focus on in-demand skills needed across the full product development life cycle—from molecule to medicine—which will also expose students and educators to the breadth of education and career pathways across biotechnology.

Through this collection, educators are equipped with strategies to engage students from diverse racial, ethnic, and cultural groups, providing them with quality, equitable, and liberating educational experiences that validate and affirm student identity.

Units are designed to be problem-based and focus on workforce skill development to empower students with the knowledge and tools to be the change in reducing health disparities in communities.

SOCIAL-EMOTIONAL LEARNING

Students will practice self management, planning, and organizational skills by selecting, gathering, and pressing a plant sample of their choice, while exercising responsible decision making by appropriately gathering the sample. Students will investigate the contributions of scientists and their work, recognizing unique perspectives and strengths of others.

CULTURALLY AND LINGUISTICALLY RESPONSIVE INSTRUCTION

By selecting a plant sample from their community, students bring real-world issues into the classroom as they wonder which plants around them could have bioactive compounds. Students can collaborate with families and the local community by exploring their backyards and local environment in a new way, creating and preserving a biodiversity collection that they are curious about.

ADVANCING INCLUSIVE RESEARCH

In this lesson, students explore their local environment and collect a plant sample that will become part of their class botanical collection. By documenting local plant biodiversity in this way, students will connect more deeply to their local living environment and build a foundation for connecting with local Indigenous communities. This will give students a practical example of ways to collect data samples from diverse groups so that they can be properly represented. Students will be building a scientific and cultural bridge between the practices of local Indigenous communities surrounding plants and that of Western scientific researchers.

COMPUTATIONAL THINKING PRACTICES

Students curate information and relevant data from iNaturalist to characterize their local plant biodiversity. They then analyze this information using the tools embedded in the iNaturalist platform to create a plant profile, connecting their knowledge of global and local patterns of biodiversity.

CONNECTION TO THE PRODUCT LIFE CYCLE

Students use the tools of botanical and field scientists to document local biodiversity. This biodiversity documentation step is a key process in identifying possible drug compounds from plants. 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.

Have you ever wondered…

What plants live in your local environment?

Some plants have medicinal uses that have been applied by local Indigenous communities for centuries (i.e., desert sage, willow). Some plants (i.e., wild ginger) are only found in the understory of coniferous forests. Some plants (i.e., white oak) characterize the ecosystem they are found in and are a keystone species that supports the survival of many other species. Each plant species is a unique example of adaptation to the local environment and holds genetic and phytochemical diversity that may be essential to solving a future human health challenge.

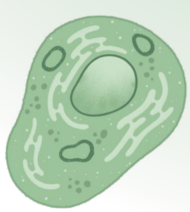
How do museum collections of biodiversity benefit scientists and future research and discoveries?

Museum collections preserve species for scientific study in a permanent form, saving valuable information from loss due to extinctions. Museum specimens can shed light on new drugs and food sources, as well as disease and pathologies that can be studied in the future.

An image of a Sacred Datura *(Datura wrightii)* flower.

How can historical museum collections inform us about extinction and climate change?

Changes in species morphology and habitat over time allows scientists to understand how climate change impacts survival and ultimately extinction. Careful documentation of specimen location using technology helps us understand where species are most successful, as well as how they respond to changing environmental conditions.



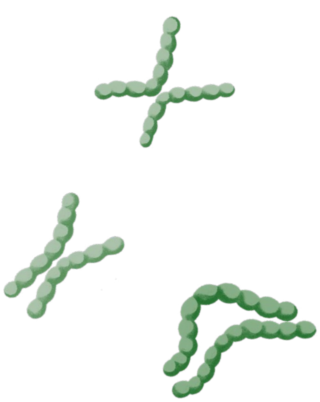
MAKE CONNECTIONS!

How does this connect to the larger unit storyline?

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.



White willow bark (Salix alba), used in herbal medicine.

How does this connect to careers?

Museum botanists study, archive, and maintain collections of plant specimens for use by scientists and public education. They research plant biology, ecology, and plant interactions with other living organisms. Many also use biotechnological tools to extract and analyze data from DNA and RNA samples to identify and characterize the specimens they catalogue in the museum.

Field scientists go out into the environment to locate unique species of plants and animals. They collect, document, and preserve biological material to help understand relationships among living things. Field scientists often travel to distant ecosystems that represent unique biodiversity. To do so, they must collaborate with government officials to obtain permits, with other scientists to create project plans and collection itineraries, and communicate with local people about the scientific work they are doing.

How does this connect to our world?

Botanical collections document the work of scientists for present and future generations.

When vast ecosystems are threatened by human development, habitat destruction, and climate change, preserving plants allows us to maintain a record of evolutionary history that may survive beyond the extinction of that individual plant or animal species.

Additionally, modern museum collections often maintain a cryobank of frozen tissue and DNA that allows scientists to continue to study genetic history even after the species itself is lost to extinction.

Day 1

LEARNING OUTCOMES

Students will be able to:

Explore the field of museum science and examine the practices of curating biological collections.

Analyze how these museum collections play a vital role in conducting research.

Understand the basics of biological procurement and preservation of specimens.

INDUSTRY AND CAREER CONNECTION

Field scientists collect plant materials for specific research projects, and as a part of biodiversity surveys intended to document local ecosystem species diversity and abundance and distribution.

Procedure

Whole Group (3 minutes)

Introduce to students the career of a museum scientist, a professional in a field of science, who manages and curates collections (of different species, for example) in a museum that is used by other scientists to conduct research. Students will profile Dr. Nathalie Nagalingum, a curator of botany at the California Academy of Sciences. Share with students that Dr. Nagalingum studies cycads, ancient endangered plants that are valued for many aspects, including bioactive compounds with medicinal uses.

Individual Work (10 minutes)

Ask students to read Dr. Nagalingum's profile and respond to the prompts in the first half of the *Who are Museum Scientists? Capture Sheet*.

Whole Group (15 minutes)

1 Share with students that they will be watching the video clip *Studying Biodiversity in the Lab* by the California Academy of Sciences.

Teacher Note > *The video clip will be viewed in three sections, not in complete chronological order, so that students can first understand why museum collections are useful to scientists, and then understand how.*

2 Show the following video sections noted below one at a time in the order shown. Ask students to complete the questions in the prompts. You can allow students time to complete question prompts after each video section before moving on.

a. First: video time stamp: 6:00–7:40

b. Second: video time stamp: 0:00–4:00

c. Third: video time stamp: 4:00–6:00

3 If time allows, have students share answers with a partner or a table group.

Continues next page >

Day 1

Continued

Procedure

Whole Group (15–17 minutes)

Share with students the *Collecting and Preserving Plant Specimens Capture Sheet* and explain that they need to complete Step 1 before the next class as homework. Instruct students to bring the plant sample with them to their next class. Step 1 asks students to collect a plant sample of their choice from their community. It is important to go over all parts of Step 1 with students to ensure that they understand key pieces of information such as:

Key Collection Documentation Instructions

- Select a location.
- Describe the location.
- Take a picture of the plant using a smartphone or other device.
- Use a tool such as Google Maps to note the exact location when collecting a plant.

Key Sample Storage Instructions

- Collect a complete sample, as much as possible (root to flower).
- Store the plant in a plastic or paper bag after gathering.
- Overnight, place the plant root in water or in a plastic bag with a wet paper towel and refrigerate.
- Bring the plant sample to the next class to press it.

Teacher Note > *It may be useful to collect 5–20 extra plant samples as a "class set" in case students are unable to. Be sure to follow the instructions for Step 1 in this case.*

Teacher Note > *As an exit ticket (if time permits) or as homework, students should add to their* ***Student Guide*** *by completing the first question for Lesson 3.*

Day 2

Procedure

LEARNING OUTCOMES

Students will be able to:

Prepare specimens for a plant press.

INDUSTRY AND CAREER CONNECTION

Museum botanists prepare collected specimens for inclusion in collections. An important part of this role is to appropriately curate collected specimens for storage, either as a morphological specimen (physical) or a genetic specimen (extracted DNA or RNA) for later study. Museum botanists also study previously collected plant materials, looking for new uses, revising understanding of taxonomic relationships, and investigating impacts of climate change on the timing of different life cycle events, among other questions.

Whole Group (5 minutes)	
1	Students should retrieve their plant samples from their homework assignment and share them with their neighbors.
2	Ask students to share with an elbow partner one thing that was surprising, interesting, or fun about the process of collecting a plant.

Teacher Note > *If students were unable to collect a plant sample, have them partner with another or give them a sample from the "class set."*

Small Group (35 minutes)	
1	Students will work through the "In Class" portion of the lab protocol (see student capture sheets). They will complete Steps 2–5 in class. Step 6 will be completed during Lesson 5 (Lab).
2	Be sure to check in with each group and with individual students as they complete the protocol.

Teacher Note > *Make sure that all plant specimens are within sheets of newspaper labeled with student names. These samples will be used by the student who collected them in Lesson 5.*

Whole Group (5 minutes)	
1	Ask students to clean up supplies and ensure that their plant specimens are in the plant press.
2	If students did not complete Step 5, they can do so as homework.

Teacher Note > *Optional: You can choose to collect all class observations on iNaturalist as described in Managing Projects.*

Teacher Note > *As an exit ticket (if time permits) or as homework, students should add to their* ***Student Guide*** *by completing the second question for Lesson 3.*

Day 3

LEARNING OUTCOMES

Students will be able to:

Demonstrate ability to build a plant profile.

Conduct research on selected plants through reputable sources.

Procedure

Whole Group (5 minutes)

1 Invite students to create a plant profile for the specimen they collected on Day 2 using the *Create a Plant Profile Capture Sheet*.

- **a.** This profile includes details that would be found in a museum exhibit on that plant.
- **b.** This profile also allows students an opportunity to gain an introduction to connections between botanical collections, traditional Indigenous ecological knowledge, and medicinal plants.

Individual Work (35 minutes)

Ask students to research their plant using Internet sources. iNaturalist, the United States Forest Service, USDA, and university websites often contain a plethora of information. Students will record their findings on the *Create a Plant Profile Capture Sheet*. They will need to include the images of their plant taken at the time of collection.

Whole Group (5 minutes)

Suggest that if students have not yet completed their profile, they can finish it as homework.

Day 4

LEARNING OUTCOMES

Students will be able to:

Analyze plants' interrelated relationships with other plants and the environments.

Examine the evolutionary history of plants and how it has changed our planet.

Hypothesize plant taxonomy for their collected samples.

Procedure

Teacher Note > *By placing their collected plant specimens into a hypothesized evolutionary tree, students will be able to articulate evidence for common ancestry. They will explore how common ancestry can aid the search for plant medicinal compounds.*

Whole Group (15 minutes)

1 As a class, watch *How did plants change our planet?* to consider how the evolutionary history of plants has altered the chemistry and biology of our planet over time.

2 On the board, brainstorm responses with students to the following prompts:

a. Describe or draw key plant adaptations over time.
Possible responses might include:

i. 480 million years ago: first land plants

Lack roots and vascular systems—need to live close to water

ii. 425 million years ago: first roots—can use water from the ground instead of needing to be next to water

b. List specific impacts of plants on the planet.
Possible responses might include:

i. 400 million years ago: roots break up rock, forming soil physically by root growth and chemically through the production of CO_2, which is an acid; plants add nutrients to soil through decay after death

ii. 360 million years ago: plants take in CO_2 and H_2O from the atmosphere and release O_2 and $C_6H_{12}O_6$, resulting in climate cooling from the lower concentration of CO_2 in the atmosphere

Fossils of soil and plants provide evidence of how early plants created soil

Fossils of soil and shells provide evidence of prehistoric temperature

Teacher Note > *Highlight that Dr. Nagalingum's work, while focused deeply on cycads, additionally elucidates how these plants interact with the broader environment and fit into the larger evolutionary history of photosynthetic organisms.*

Continues next page >

Day 4

Continued

Procedure

3 Show students the *Phylogenetic Tree of Green Plants* and the *Phylogenetic Tree of Flowering Plants (Angiosperms)*. Explain that a phylogenetic tree displays shared common ancestry among related species. Invite students to consider how the two trees relate to each other.

a. The *Phylogenetic Tree of Green Plants* is a “zoomed out” view of how all plants (photosynthetic organisms) are related to one another across evolutionary history. The *Phylogenetic Tree of Flowering Plants (Angiosperms)* zooms in on the rightmost portion of the green plants tree and considers only plants that flower to produce seeds.

4 Ask students to share what they wonder about the methods used to construct the figure and what evidence was considered to create each hypothesis of evolutionary history.

a. Remind students that we as humans were not present to witness the origin of photosynthetic organisms (almost 3.6 *billion!* years ago), so scientists use DNA, fossils, morphology, and current plant relationships to infer the evolutionary history of these species over time.

b. Thus, we call phylogenetic trees “hypotheses” as they may be revised as new evidence arises and our understanding of evolutionary history improves.

5 Encourage students to display their printed plant profile from Day 3 on the board or on the walls. Ask each student to provide a unique number to the bottom of their plant profile, so that students can work in smaller groups to create evolutionary hypotheses.

6 Ask students to recall that up until the mid 1970s, taxonomists, botanists, and museum scientists only used physical and behavioral evidence to group plants into categories (called Phyla, Orders, Classes, and Families). This process of grouping based on similarity provides key evidence of *evolutionary relationships*.

Continues next page >

Day 4
Continued

Procedure

Small Group (15 minutes)		
1		Ask students to collaborate in groups and arrange the numbered plant profiles into smaller clusters based on physical or ecological similarities. This work could take place on a large sticky note or on a large group white board.
2		Ask students to answer the following question:
	a.	What physical features make these plants more or less closely related to each other than they are to other specimens in the collection?
	b.	Students should justify their choices using bullet points on their white board to note similarities within clusters and differences between clusters.
3		Ask students to create a family tree, arranging their clusters based on their hypotheses of how they are related to one another.
4		Share a reflection that understanding evolutionary relationships is one form of evidence that can be used to identify plants that may have useful compounds. The logic of this type of analysis is explained in the teacher note below.

Teacher Note > *A concrete, well-studied example of how evolutionary relationships inform the search for bioactive compounds can be found in research on the neurotoxins of Exploring the Evolution of Spider Venom to Improve Human Health and Extremely Rapid Evolution of Cone Snail Toxins. The protein sequence data for the toxic spiders and cone snails is compared to the non-toxic venom, allowing scientists to understand the precise protein structure that leads to the human health response. This allows scientists to develop novel medicinal compounds and antivenom that might be universal to a larger group rather than to a specific species, like the brown recluse or black widow. Similar principles can be applied to plant evolution. This allows scientists to use resources, including museum collections, more efficiently.*

Teacher Note > *As an exit ticket (if time permits) or as homework, students should add to their **Student Guide** by completing the final question for Lesson 3.*

National Standards

Next Generation Science Standards	**LS 2-2 Ecosystems: Interactions, Energy, and Dynamics** Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
	Science and Engineering Practices Planning and Carrying Out Investigations Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. Constructing Explanations and Designing Solutions Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.
Career and Technical Education (CTE)	**A2.3** Understand the necessity for accurate documentation and record keeping.
	A8.8 Perform specimen collection, label samples, and prepare samples for testing.
	A8.9 Handle, transport, and store samples safely.
	5.4 Interpret information and draw conclusions, based on the best analysis, to make informed decisions.

Who are Museum Scientists? Capture Sheet

ANSWER KEY — **Do not share with students**

Directions
Read about Nathalie Nagalingum and review Science Hero: Nathalie Nagalingum, then answer the questions on the following page.

1. What strikes you about Dr. Nagalingum's personal and professional journey?

Answers will vary.

2. Dr. Nagalingum is interested in learning how to paint both plant and non-plant subjects. Dr. Nagalingum is passionate about diversifying scientific ideas and increasing representation of racially diverse groups and women. What issues are you passionate about, outside of your academic interests?

Answers will vary.

3. Cycads are threatened by human poachers who are interested in selling them to plant enthusiasts and collectors worldwide. Watch *The Price of Plant Poaching*. What strategies and scientific tools does Dr. Nagalingum's team utilize to conserve this important plant group?

— International regulations govern the trading of cycads.

— Growers must produce documentation showing where cycads came from to discourage illegal trading.

— Microchips are embedded in cycad trunks to track stolen plants.

Dr. Nagalingum's team is looking at cycad DNA, and tracking cycads that have been moved from one region to another, to determine if that is best for the health of those particular species.

4. How are genomics and genetics important to Dr. Nagalingum's conservation research and museum science? Use *Saving Cycads with Science* to answer this question.

Studying genomics and genetics provides information about

— Potential new species

— Genetic diversity of individual species

— Which species in particular need conservation efforts in botanical gardens and museums

— Species with greater genetic diversity (a "genetic hotspot") to target for conservation efforts

5. How does Dr. Nagalingum utilize museum collections during her research?

Dr. Nagalingum uses museum collections to study cycad DNA. The museum collection provides a framework for what the cycad research community knows about this plant group, and allows Dr. Nagalingum and other scientists to "visit" distant places and historical times without going on a new collection trip.

Continues next page >

Who are Museum Scientists? Capture Sheet

ANSWER KEY **Do not share with students**

Continued

6. How are museum collections documenting biodiversity created and used by scientists? Watch the last two minutes of the *Studying Biodiversity in the Lab* video clip. According to scientists at the California Academy of Sciences:
   a. How does building a biodiversity collection influence other areas of biology and science?
   b. What are some benefits of documenting and maintaining biodiversity collections in a museum or lab? (Video time stamp: 6:00–7:40)

— Information is preserved forever.
— Evolutionary relationships can be examined.
— Diseases and pathologies can be studied in the future.
— New drugs, food sources, and ways to protect biodiversity can be learned.

7. Next, watch the first four minutes of the *Studying Biodiversity in the Lab* video to answer the questions below. (Video time stamp: 0:00–4:00)
   a. What kind of information does a catalog number of a specimen provide?
   b. Why is identifying the location of a specimen the most important information (*even more important than what you think the species is*)?

The catalog number tells you where a specimen was found, its geographic coordinates, what the environment or conditions were like, and any other special information related to the specimen.

You might not know for sure what the species is at the time, or you may have collected several species together in a "lot". If you know where they were collected from, you can identify the species with more certainty later. Also, when species are misidentified and then corrected later, knowing where the specimen came from is very important.

8. How can we use technology to precisely identify where a specimen was found?

Georeferencing can be done to show the exact coordinates of where on Earth the specimen came from using GIS, a Geographic Information System, on a smartphone; the coordinates are stored in a database.

9. Finally, watch minutes 4–6 of the *Studying Biodiversity in the Lab* video and explain how scientists can use technology to identify a species at a later time after cataloging its location. (Video time stamp: 4:00–6:00)

Traditionally, scientists studied the morphology (shape) of an organism to identify it, but today they use molecular techniques such as genetic sequencing of an organism's DNA to identify the species.

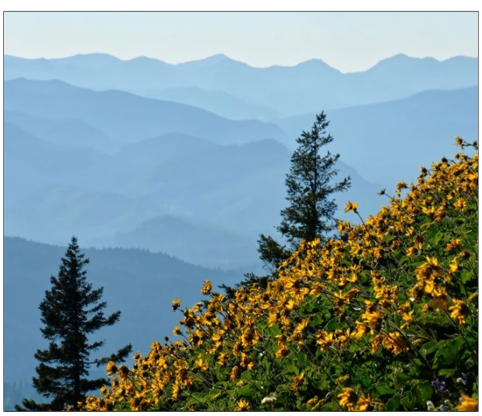
Create a Plant Profile Capture Sheet

ANSWER KEY — **Do not share with students**

Directions
Create a Plant Profile. Provide details about the collection event and your selected plant's ecology by answering the following questions.

Answers will vary with the plant chosen.
Below is an example.

Plant Profile



1	***Scientific name***, Common name *(Write scientific name in bold and italic font, genus capitalized and species lowercase)* ***Balsamorhiza sagittata,*** Arrowleaf balsamroot
2	Your name and school Anne Peters Franklin High School
3	Collection location *(park, city, state, country)* Bingen, WA, USA
4	GPS location data 45.7201176°N, -121.7050749°W
5	Collection date *(day/month/year)* 7 April 2021

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Create a Plant Profile Capture Sheet

ANSWER KEY — **Do not share with students**

Continued

1 Where is the plant found on the planet? Describe its geographic range.	Arrowleaf balsamroot is found in cold, dry areas of the West, from the Sierra Nevada east to Colorado and extending north into Canada.
2 Describe the ecosystem where the plant was found Is it a forest? Grassland? Urban area? What elevation was it located at? What other species are found in the area?	Arrowleaf balsamroot is found in grasslands, sagebrush steppe, and in both valleys and montane ecosystems.
3 How many individuals of this plant are there? Is it common, abundant, rare, endemic, threatened, or endangered?	This plant is common in its range. It is a forb/herb.

Continues next page >

Create a Plant Profile Capture Sheet

ANSWER KEY **Do not share with students**

Continued

4 How long does the plant live? How does it reproduce? Is it an annual? Perennial? A Tree? How long after sprouting does it take to go to seed?	Arrowleaf balsamroot is a perennial plant that reproduces through pollination and going to seed. It cannot be transplanted easily. Seeds fall in the fall and young plants emerge in the spring.
5 What human conditions, if any, is your plant known to treat? Use .gov or .edu sources to research this, when possible.	It is used to treat pain from burns, wounds, and bruises. It is also used to treat tuberculosis and whooping cough.
6 What Indigenous cultures utilize this plant in traditional medicine, if known?	The Cheyenne tribe steamed the plant and inhaled the vapors to cure stomach pain and headaches. Many other tribes, including the Nez Perce, Kootenai, and Salish, use this plant medicinally. This plant is also a significant food source and all parts of the plant were utilized for both food and medicine.

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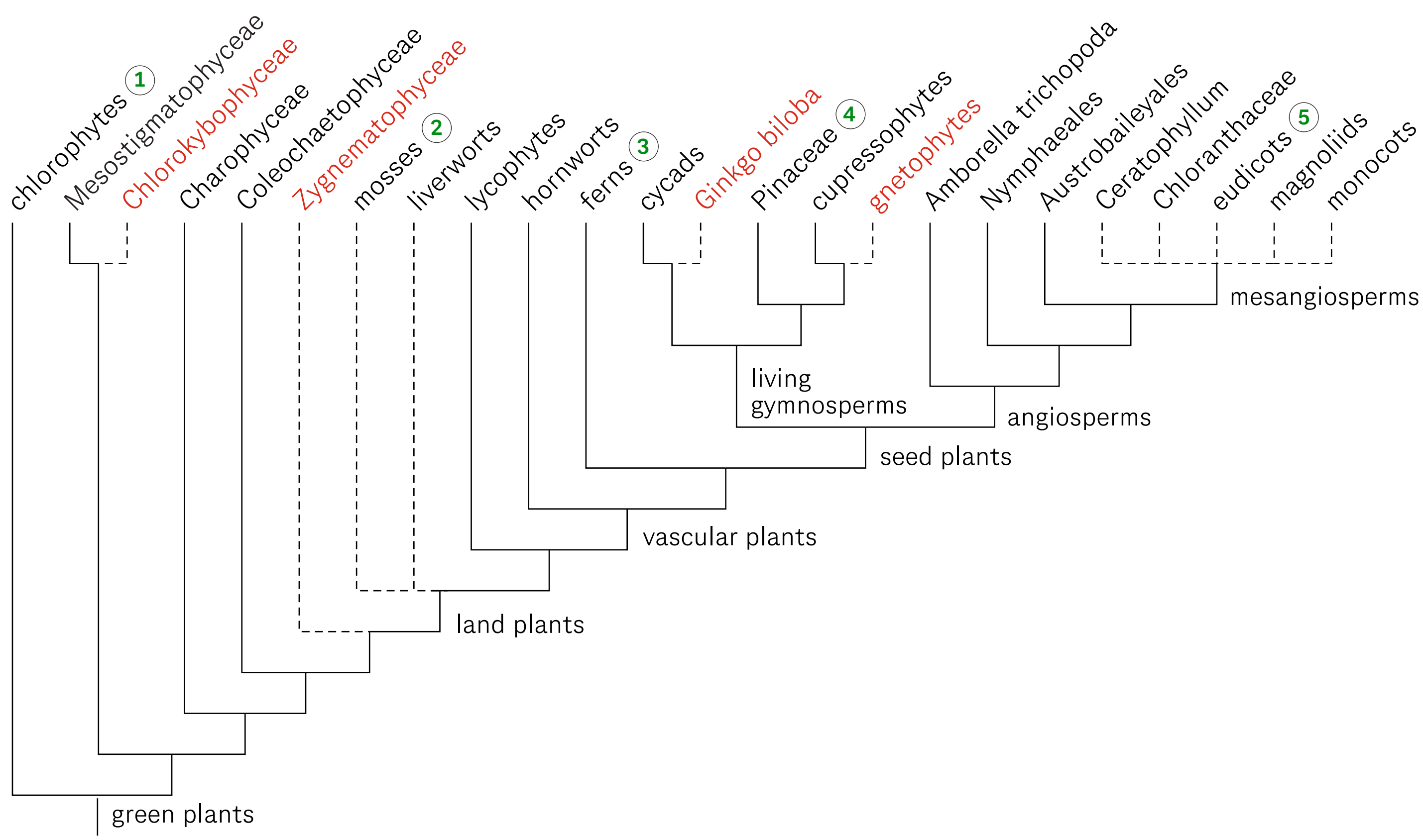
Student Resources

Phylogenetic Tree of Green Plants



Legend

This phylogenetic tree of green plants shows how they are evolutionarily related to each other, as inferred in the paper:

Plastid Phylogenomics and Green Plant Phylogeny: Almost Full Circle But Not Quite There.

Dashed lines indicate unresolved placements—that is, there is not enough data to determine if one group split from the common ancestor before others.

– – –

Relationships that are well resolved in the tree but contentious are highlighted in red.

red text

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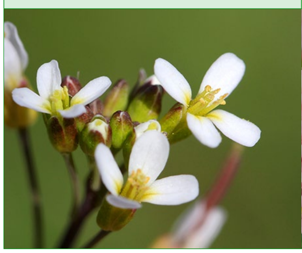
Student Resources

Continued

Phylogenetic Tree of Flowering Plants (Angiosperms)

1 Thale Cress

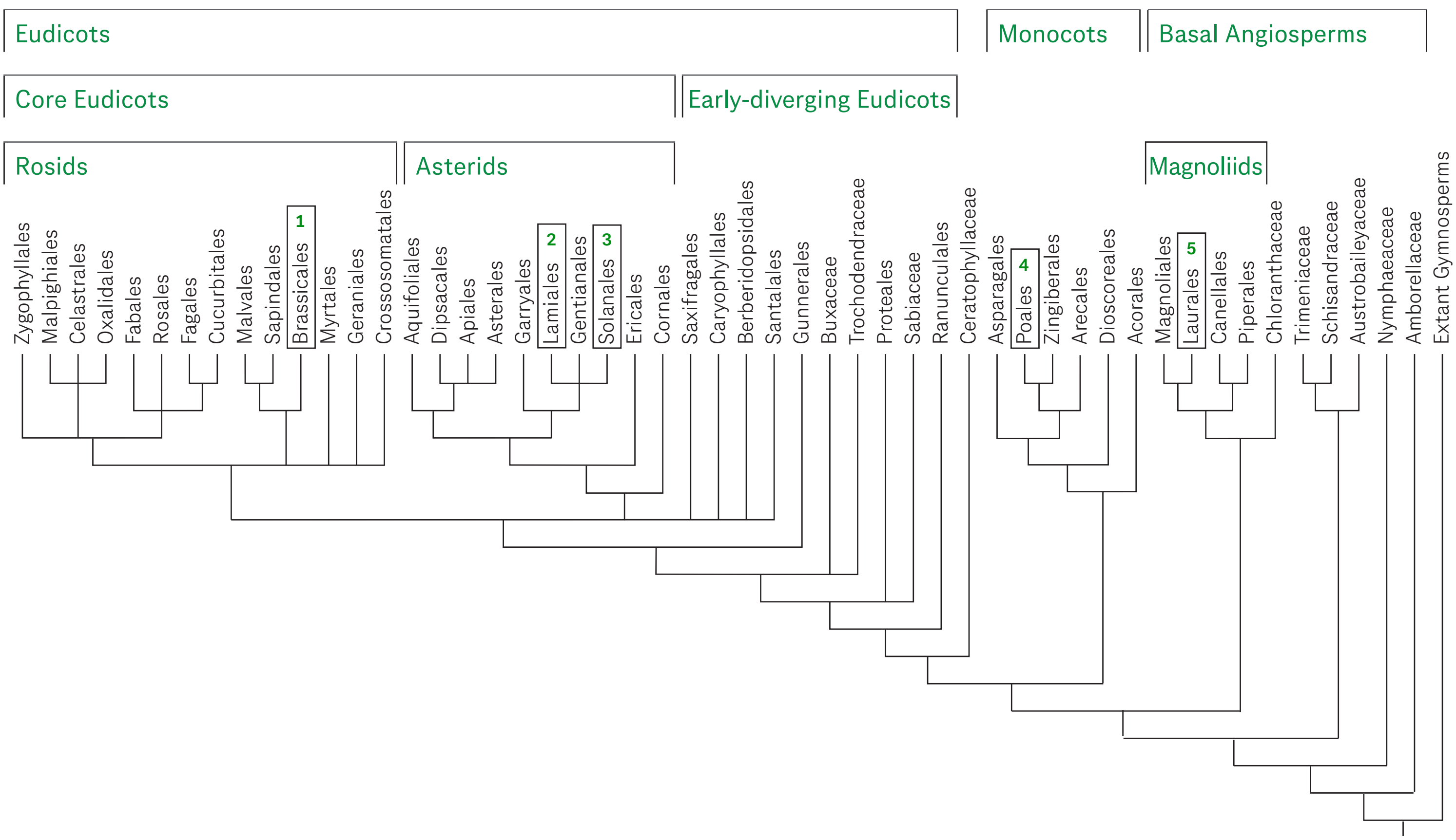


2 Snapdragons

3 Tomato

4 Rice

5 Avocado



Legend

This phylogenetic tree of angiosperms shows how these flowering plants are evolutionarily related to each other, as hypothesized by data gathered from chloroplast genomes.

Black boxes indicate orders of plants with representative images above:

Brassicales (such as the thale cress), Lamiales (such as the snapdragon), Solanales (such as the tomato), and Poales (such as rice).

Other non-model fruit based crops with extensive genomic resources include cotton and cocoa (Malvales); apple, plum, peach, and strawberry (Rosales); blueberry (Ericales); grape (Vitales); orange (Sapindales); all eudicots.

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Who are Museum Scientists? Capture Sheet

Directions
Read about Nathalie Nagalingum and review Science Hero: Nathalie Nagalingum, then answer the questions on the following page.

Dr. Nathalie Nagalingum
Associate Curator
California Academy of Sciences

Dr. Nathalie Nagalingum studies cycads at the California Academy of Sciences. She uses herbariums (plant museums) and genomic tools. She works closely with stakeholders in a range of field site locations to conserve a species under threat from climate change, poaching, and human encroachment.

Cycads are important species that have several medicinal properties due to the presence of bioactive compounds used to treat cancers, piles, gastrointestinal issues, and other ailments, as well as nutritional benefits. If you are interested in some examples of the medicinal use of cycads, review *Ethnobotanical, Phytochemical and Pharmacological Potential of Cycas revoluta Thunb—A review*.

Continues next page >

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Who are Museum Scientists? Capture Sheet

Continued

1. What strikes you about Dr. Nagalingum's personal and professional journey?

2. Dr. Nagalingum is interested in learning how to paint both plant and non-plant subjects. Dr. Nagalingum is passionate about diversifying scientific ideas and increasing representation of racially diverse groups and women. What issues are you passionate about, outside of your academic interests?

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Who are Museum Scientists? Capture Sheet

Continued

3. Cycads are threatened by human poachers who are interested in selling them to plant enthusiasts and collectors worldwide. Watch *The Price of Plant Poaching*. What strategies and scientific tools does Dr. Nagalingum's team utilize to conserve this important plant group?

4. How are genomics and genetics important to Dr. Nagalingum's conservation research and museum science? Use *Saving Cycads with Science* to answer this question.

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Who are Museum Scientists? Capture Sheet

Continued

5. How does Dr. Nagalingum utilize museum collections during her research?

6. How are museum collections documenting biodiversity created and used by scientists? Watch the last two minutes of the *Studying Biodiversity in the Lab* video clip. According to scientists at the California Academy of Sciences:
   a. How does building a biodiversity collection influence other areas of biology and science?
   b. What are some benefits of documenting and maintaining biodiversity collections in a museum or lab? (Video time stamp: 6:00–7:40)

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Who are Museum Scientists? Capture Sheet

Continued

7. Next, watch the first four minutes of the *Studying Biodiversity in the Lab* video to answer the questions below. (Video time stamp: 0:00–4:00)
   a. What kind of information does a catalog number of a specimen provide?
   b. Why is identifying the location of a specimen the most important information (*even more important than what you think the species is*)?

8. How can we use technology to precisely identify where a specimen was found?

9. Finally, watch minutes 4–6 of the *Studying Biodiversity in the Lab* video and explain how scientists can use technology to identify a species at a later time after cataloging its location. (Video time stamp: 4:00–6:00)

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Collecting and Preserving Plant Specimens Capture Sheet

Directions
Our class is creating a botanical collection of plants that are present in our local environment. We will gather plants, prepare them for storage, and communicate our observations. For an overview of our steps, check this DIY Plant Pressing protocol from the Field Museum.

Step I: Gather your plants *(as homework)*

A Decide where you would like to collect your plant sample.

Your plant specimen could be collected from your backyard, a local natural area, or even a parking lot.

1. National Forests or Bureau of Land Management (BLM) land are good choices if you are specifically interested in learning more about the local flora.

Do not collect samples from wilderness areas. Note also that the National Park Service (NPS) (which includes National Monuments) allows almost no collecting of any kind on its lands.

2. If you are interested in how humans have shifted the local flora, a local park, a parking lot, your backyard, or your school are all also good choices for locating a plant sample.

B Decide which plant to collect.

For the purposes of our class collection, choose an herb/forb (in botany, this means a small plant, not necessarily something you cook with), a shrub, a fern, a moss, or a grass.

1. Identify your plant. Use a guidebook or *iNaturalists' Identify Page*.
2. Before taking any plant samples, ensure you are not removing or harming protected plants. *USDA Plants Database* is a good place to check.
3. The plant you select should be just one of many similar plants in an area. If the plant is unique, choose a different plant to collect so as to not remove a plant that is locally rare.

C Take a picture of your plant in its natural habitat. Watch *How to take better photos for iNaturalist* for a few tips.

D Collect your plant.

Gather as complete a sample as you can, including the roots and any flowers.

1. Note the name of the location, along with the town, state, and country. Capture a few notes about the habitat in which your plant was located. Record the date and time. See the data collection example below.
2. Store your plant specimen in a plastic bag with a damp paper towel, being careful not to crush or damage it. Place your plant specimen in the refrigerator overnight.
3. Remember to bring your plant specimen to class for the next steps.

Data Collection Example

Your collection location *Example: Al Raught Park, St.Helens, Washington, USA*
Your collection site description *Example: Douglas Fir Forest, 2500 ft elevation, under canopy*
Date and time of your plant collection *Example: 7 April 2021, 13:00 or 1:00 PM*

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Collecting and Preserving Plant Specimens Capture Sheet

Continued

Step II: Prepare your plant for long term storage *(in class)*

A Prepare your plant specimen for the press.

Watch Using A Plant Press to prepare your specimen for archival.

1. Lay your plant flat on two or three sheets of newspaper, and fold the newspaper over the plant.
2. Write your name, class period, and collection location on the outside of your newspaper.
3. Write a description of physical characteristics or traits of your plant that might change after drying the plant.

   These might include leaf pattern (alternate, opposite, whorled), flower color and shape, leaf type (compound or single). For more details, review American Museum of Natural History's Plant Morphology.

B Press your plant specimen.

You will layer your plant specimen with your class in a plant press.

1. Each newspaper-plant specimen layer will be separated by a page of blotting paper. The entire stack of newspaper-plant specimens and blotting paper will be sandwiched by wood or cardboard on top and bottom.
2. Secure the plant press using a strap or heavy weights (textbooks work well here).
3. The plants will take one to two weeks to dry. Check on your plants periodically and change the blotting paper if it is wet.

Step III: Communicate your observations *(in class)*

A Post details about your plant specimen to iNaturalist.

Create an iNaturalist account.

1. Select the privacy options that make sense to you. If you have questions, ask your teacher for advice.
2. Identify the best two or three images of your plant specimen from the field collection site, and make an observation on iNaturalist.

   How to Make an Observation on iNaturalist using our Mobile App or *How to Use iNaturalist's Photo Uploader*.
3. If your teacher has created a class project, add your observation to your class project.

B Prepare your label.

Labels are key tools that provide the collection location and date, invaluable data for future researchers. Prepare your label and affix it to the plant specimen when fully dried. Refer to the label template and example below.

C Explore your classmates' observations on iNaturalist.

If your teacher set up a project, you can explore and help identify the plants that your classmates collected.

Label Template and Example:

Scientific Name
(in bold and italic font, genus capitalized and species lowercase)
Your name and school name/Collection date *(day/month/year)*
Collection location *(park, city, state, country)*
GPS location data
Photograph info *(iNaturalist observation URL)*

Balsamorhiza sagittata
Anne Peters, Franklin High School/7 April 2021
Willard, Washington, USA
Photo by drew_meyer: *https://www.inaturalist.org/observations/73440304*

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Create a Plant Profile Capture Sheet

Directions

Create a Plant Profile. Provide details about the collection event and your selected plant's ecology by answering the following questions.

Plant Profile

Paste a photo of your plant in its field location here.	1	***Scientific name***, Common name *(Write scientific name in bold and italic font, genus capitalized and species lowercase)*
	2	Your name and school
Optional: Paste photo of the field site where you collected the plant here. *This gives your audience a broader sense of the ecosytem you describe.*	3	Collection location *(park, city, state, country)*
	4	GPS location data
	5	Collection date *(day/month/year)*

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Create a Plant Profile Capture Sheet

Continued

1 Where is the plant found on the planet? Describe its geographic range.	
2 Describe the ecosystem where the plant was found. Is it a forest? Grassland? Urban area? What elevation was it located at? What other species are found in the area?	
3 How many individuals of this plant are there? Is it common, abundant, rare, endemic, threatened, or endangered?	

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Create a Plant Profile Capture Sheet

Continued

4 How long does the plant live? How does it reproduce? Is it an annual? Perennial? A tree? How long after sprouting does it take to go to seed?	
5 What human conditions, if any, is your plant known to treat? Use .gov or .edu sources to research this, when possible.	
6 What Indigenous cultures utilize this plant in traditional medicine, if known?	

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Rubric for Biotech Unit 7
Lesson 3

Planning and carrying out investigations

Observable features of the student journal	Meets Expectations 8–10 points	Progressing 5–7 points	No attempt 0 points
Research			
a. Students make a plan to collect botanical specimens in their community.			
Collection			
a. Students collect a full botanical specimen, including roots and flowers where possible.			
b. Students document the physical location of the plant using words and GPS location data.			
Presentation			
a. Students connect their collected specimens with museum botanical specimens.			
b. Students participate in and make connections between the physical traits of their botanical specimen with that of other collected botanical specimens.			
Final Score			
Grade			