The Gateway to Tree Science

Students and Teachers (Grades 6-12) Field Trip Resources

The Gateway to Tree Science is divided into six (6) sections and the panels for each section are color coded and labeled along the side (Introduction – blue; Choosing the Right Tree – aqua; Caring for Urban Trees – dark green; Addressing the Challenges of Urban Soils – light green; Cultivating Resilient Trees – green/brown; and Laying the Groundwork – tan).

Exhibit Key Messages:

- The natural history of trees and how The Arboretum studies them.
- The best practices in tree care and the science behind those practices.
- The research that contributes to our understanding of trees: how they work; how they thrive in nature and in urban communities; and what wild and cultivated tree populations around the world can teach us about conservation and management.

Next Generation Science Standards (NGSS) Connection:

- MS-LS2-5 - Evaluate competing design solutions for maintaining biodiversity and ecosystem services.
- HS-LS2-7 - Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Resource Overview:

- Logistical support/details for your trip
- A Self-Guided Hunt for Students Grades 9-12
    - Part 1: Find the Fiction Activity (30 minutes)
    - Part 2: Choose Your Own Adventure Activity (45 minutes)
- Follow-Up Resources

Logistical Support/Details for Your Trip

Prior to your trip:

- **Logistical Prep:**
    - **Review The Arboretum's map and field trip prep materials.** This includes the chaperone field trip letter, group planning document, and self-guided information letter.
    - **Determine your content goals for the trip**. Do you want the students to take photos of what they see? Do you want them to collect information or notes?
    - **Determine your route**. Based on the plans for your day, be sure to map out where you want to visit. For The Gateway to Tree Science Exhibit, you can hike from the Visitor Center and park in Parking Lot One (1) (the main lot) OR you can park near Parking Lot Five (5) or Eight (8), depending on the size of your vehicles(s). Chart your hike while considering bus parking, lunch location, and other parts of your day. Lunch space is not reserved, but the map identifies several picnic locations where your group can stop to eat.
    - **Curriculum Prep/Activities:**

- **Review your expectations for the trip.** Show students what they will do during the trip. Outline your goals and what you want them to do or collect while they are onsite.
- **Familiarize your students with The Arboretum.** Get to know The Arboretum before your visit. View our online exhibits through Google Cultural Institute:
- https://www.google.com/culturalinstitute/beta/partner/the-morton-arboretum
  - Can you imagine a world without trees?
  - What is an Arboretum?
  - Great Trees

Day of Your Field Trip:

- Arrive with time to travel to the start of your hiking location. The Arboretum contains sixteen (16) miles of trails and nine (9) miles of roads. Transportation on the property by car to different locations can take up to twenty (20) minutes.
- At the gatehouse entrance, indicate the name of your school or group. It is recommended that you also bring a copy of your confirmation statement.
- Once you have arrived to your hiking location, unload and divide into groups. Use this hiking guide to prompt your students with questions and observations as they encounter The Gateway to Tree Science exhibit.

Following Your Trip:

- Determine how you want students to summarize their learning.
- Utilize any of the extension resources highlighted below:
  - The Gateway to Tree Science Graphic Novels: The Canopy Career Chronicles
  - Planted Finding Your Roots in STEM Careers Podcast is a newly released podcast from The Morton Arboretum, introduces listeners to plant professionals with amazing careers and explores the journeys they took to get there.
    - Listen Online or download on your tablet/mobile device.
    - Explore resources and activities for each episode.
  - Seed Your Future: Seed Your Future is the movement to promote horticulture and inspire people to pursue careers working with plants. Below is a list of resources this organization has created to promote horticulture in classroom instruction. Activities are geared towards grades 6-8.
    - What's Your Plant Power?: Interactive Module that shows students plant parts and their functions, while highlighting plant powers and unique features.
    - Bloom: Learn more about Green Collar Jobs in this Scholastic Article: http://www.scholastic.com/bloom/pdfs/Bloom_StudentMagazine.pdf
      - Use as a reading guide for this article: http://www.scholastic.com/bloom/pdfs/Bloom_Green-CollarCareersResearchActivitySheet.pdf
    - Disruptive Scenarios: http://www.scholastic.com/bloom/pdfs/Bloom_ScenariosActivitySheet.pdf
    - Horticulture Careers Board Game:
      - Game Board: http://www.scholastic.com/bloom/pdfs/Bloom_GameBoard.pdf
      - Instructions: http://www.scholastic.com/bloom/pdfs/Bloom_GameInstructions.pdf
      - Game Board Trivia Cards: http://www.scholastic.com/bloom/pdfs/Bloom_GameTriviaCards.pdf

The Gateway to Tree Science

Student and Teachers (Grades 6-12) Field Trip Resources

A Self-Guided Hunt for Students Grades 9-12

Allow students time to visit The Gateway to Tree Science Exhibit and learn about the pathways that scientists follow to inform the decisions we make about tree care. Students will understand how Arboretum science can update ways we care for the trees in their school yard or community. Additionally, students will get an in-depth look at what real-world tree science looks like. This resource is divided into two (2) parts and is aligned to NGSS for grades 6-12.

Part One: Find the fiction in the statements below and uncover The Gateway to Tree Science. (30 minutes)

Directions: Walk towards the pavilion from the parking lot. The panels with the information that you seek will be located anywhere near the pavilion structure. Read each series of statements and find the statements that are "fiction" or false. Provide reasoning or support for your statement. (Statements are generally listed in the order of the information presented in the first few panels.)

How does a Tree Live?

A. Tree roots can be as thick as a tree's branches, but cannot be microscopic.
B. Leaves are like the lungs of a tree because most gas exchange occurs here.
C. Tree rings are formed by xylem tissue (a type of vascular tissue in the plant). Trees produce a new layer of xylem each year.
   Fiction: _____

   Reasoning/Support for your selection:

   _____

   _____

Measuring a Tree's Vital Signs

A. Just like how our bodies contain specialized tissue types (muscle, bone, connective tissue, skin), trees contain a few major tissue types including: leaf, wood, vascular cambium and roots.
B. A Tree Observatory can integrate a number of different types of data to understand how trees use water, respond to environmental change, and allocate resources for timed blooming and bud burst.
C. A sap flow meter can help provide a window into root system dynamics.
   Fiction: _____

   Reasoning/Support for your selection:

   _____

   _____

How Do Scientists Discover New Knowledge (A closer look at Jan Baptista van Helmont)

A. In the 1600s, it was believed by many that trees were a creation of the soil they grew in. Observing that the soil around the tree did not disappear, grew into a question about "what trees are made of" for scientist, Jan Baptista van Helmont.
B. Van Helmont's hypothesis was that trees were made of water, not soil. He tested this hypothesis by conducting a study using 200 pounds of soil and a five (5) pound willow tree.
C. Once van Helmont experimented and drew a conclusion about what trees were made of, everyone accepted his results and moved on to learn more about soil.

Fiction: _____

Reasoning/Support for your selection:

_____

_____

How Can We Help Trees Survive in Urban Areas?

A. Diversity of tree species in an ecosystem (urban or natural) helps increase an ecosystem's resilience to infestations of pests and disease and environmental disasters.
B. Diversity is only important when you are looking at the types/species of trees, but not the age diversity of trees in an ecosystem.
C. Understanding trees in their natural setting can help us care for trees in an urban setting.

Fiction: _____

Reasoning/Support for your selection:

_____

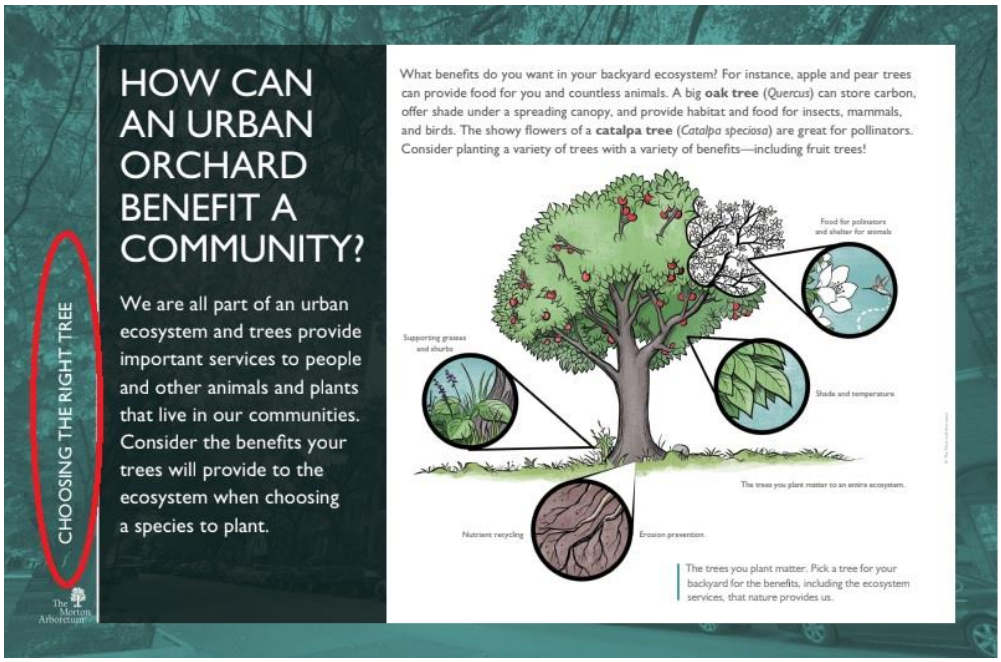
_____

The Gateway to Tree Science

Student and Teachers (Grades 6-12) Field Trip Resources

Part Two: Choose Your Own Adventure. Take on the role of understanding a different scientists' point of view when it comes to positively impacting biodiversity and mitigating human activities that effect ecosystem/tree health. Allow students to "choose" which scientist they would like to be. Students can work in homogeneous groups, either as the same role or in heterogeneous teams where each individual is a different scientist. (30 - 45 minutes)

Note: The Gateway to Tree Science is divided into six (6) sections. (Including the introduction area which you just toured). Each role will not visit all of the sections. However, use the labels on the side of the panels to indicate which section students are being asked to visit. For example, if the role indicates you are should visit "Choosing the Right Tree," then you would visit the aqua-colored panels, with "Choosing the Right Tree" printed along the side (example below).



Directions: Read the scientist's profile and then visit different components of The Gateway to Tree Science Exhibit at The Morton Arboretum. Answer the questions and collect information along the way. After you have collected this information, you can answer the follow-up thoughts or questions. Use the information to make an argument with evidence for why research in your scientist's role/area is critical to reducing the impacts of human activities on the environment (and trees).

Follow-Up: Have students share their findings to their group or class. Encourage students to document the sections they visit by taking notes or photographing the demonstrations present in the exhibit. Additionally, for each section there are extensions or web resources that help bring more of this content to life. Utilize these resources when you return from your visit.

Role #1 – Gettin' Dirty – Soil scientists for urban trees

"I am a soil scientist. I care deeply about the benefits that trees provide in an ecosystem and how they can positively influence the diversity of other species within their ecosystem. Soils need healthy plants to provide the right balance of carbon and nitrogen in the soil. Trees need healthy soil to survive and function. I am interested in finding ways to improve soil health for different types of trees in urban and natural environments. Investigate the soil factors that impact tree health and learn about how soil research can positively impact tree growth and help biodiversity."

- Visit any of the "Caring for Urban Trees" (dark green) panels. Uncover two (2) factors that impact trees in urban settings.
  - _____
  - _____

- Visit the "Addressing the Challenges of Urban Soils" (light green panels). Look at the demonstrations of trees planted under different pavement conditions.
  - What do you observe about the trees and soil conditions planted in these demonstrations?
    _____
  - What would you predict will change over time with these trees as they grow?
    _____

- True or False: Do you think different species of trees are more adapted to survive in urban environment than other species? Give your reasoning.
  - _____

Extension: Learn more about the "day in the life of" a scientist working with soils to understand the role they play in trees and the environment: https://www.youtube.com/watch?v=NrkEjs6uprg&feature=youtu.be

Follow-up thoughts:

- Why do you think caring for the soils of urban trees is important?

_____

- Think about the images of urban tree plantings that you examined in The Gateway to Tree Science Exhibit - Why do you think caring for these trees is important? What can they provide to the urban ecosystem?

_____

Role # 2 - Here I Come to Save the Day! – Conservation biologist to protect threatened trees

"I am a conservation biologist. I want to preserve endangered and threatened trees around the world. Having ecosystems rich with biodiversity of species can help ensure the future of trees and humans. Often times, human activity negatively impacts tree populations and ecosystem biodiversity. Learn about the common trees you may not know are endangered, and investigate how I evaluate different tree species for conservation."

- Visit "Laying the Groundwork" and find "Why do we study and conserve oaks?" Give two (2) reasons why oaks are an important group of species to conserve.
    - _____
    - _____

- Continue to review the panels in this area "Laying the Groundwork." Visit "Why does The Arboretum create *ex situ* Collections?"
    - What is an "*ex situ*" collection:
        - _____
        - _____

- Continue to review the panels in this area "Laying the Groundwork." Visit "How does The Arboretum choose which trees to collect and preserve?"
    - Describe how creating "*ex situ*" collections help ensure that human impact on biodiversity limits or reduces the threat of extinction?
        - _____
        - _____

Extension: Learn more about the "red list" of endangered or threatened trees.

- What is the ICUN Redlist?
- Why is it considered the Barometer of Life?
- Press Release on Rare and Endangered Oaks: https://www.mortonarb.org/news/arboretum-researchers-find-nearly-one-fourth-oak-species-us-are-conservation-concern

Follow-up Thoughts:

- Why is it important to conserve different species of trees?

  _____

- What are some ways that humans impact natural populations of trees and can create threats for extinction?

  _____

Role # 3- That's Right, I MAKE Trees. – Tree breeding to combat tree disease and pests

"I am a tree breeder. I love observing the unique features of trees and finding ways to highlight these features in new varieties and cultivars[1]. Trees are under threat from pests and diseases. Finding trees that are more resistant, but not immune to these threats, helps to prevent against species loss. Uncover the process of creating hybrid trees, the threats currently facing some common trees, and why tree breeding can help the diversity of tree species."

- Visit "Cultivating Resilient Trees" panels. Find "What is a hybrid?" Make observations about the trees in front of you and behind these panels. Next, answer the questions below:
  - How is the process used to create a hybrid different than the simplest way to propagate? Which parts of the tree are being used?

    _____
  - True or False: Hybridization occurs naturally, but humans have also adapted the process to create resilient and beautiful trees.

    _____
- Continue to review the panels in this area. Visit "Dutch Elm Disease." What is the name of the hybrid Elm, developed at The Morton Arboretum, that was cultivated to be more resistant to Dutch Elm Disease?

  _____
- Continue to review the panels in this area. Visit the various tree pest and diseases panels (cedar-apple rust, apple scab, Japanese beetles, sycamore anthracnose, emerald ash borer). Record one thing you learned about these threats to tree health:

  _____

Extension:

- Make your own plant observations for breeding. Choose four (4) favorite plants and make observations that you think could be beneficial to cultivate. Use this resource from Scholastic and Seed Your Future: http://www.scholastic.com/bloom/pdfs/Bloom_MakeHybridConnections.pdf

Follow-up Thoughts:

- Why are creating hybrids and cultivating new trees important to long-term biodiversity and conservation?

  _____
- Think about ways humans may impact the spread of invasive pests. Record your thoughts below.

  _____

[1] The term **cultivar** most commonly refers to an assemblage of plants selected for desirable characters that are maintained during propagation. Most **cultivars** arose in cultivation, but a few are special selections from the wild. Propagation is the process to produce seedlings by germinating seeds, growing cuttings or by using methods to encourage plant reproduction and growth.

Role # 4 - It's All in the Family - Research scientist in plant systematics to understand how species are related to inform conservation

"I am a research scientist focused on the interconnectivity of species. I love to understand how species are related to each other and how we can use models to predict which species, and families will be able to adapt to environmental changes. The "Tree of Life" helps me understand common origins for different species and help identify species and traits we may need more in the future as environmental change occurs. Uncover the "Tree of Life," and learn about the evolution of oaks, a critical North American species.

- Visit "Laying the Groundwork" panels and find "How Are Different Oak Species Related and Why Does It Matter?" What is a phylogenetic tree? What does it the Oak Tree of Life tell us?

  _____

  _____

- Continue to explore the panels in this area. Visit the stone patio, which is a visual representation of the Oak Tree of Life. What did you learn about the relationship between red oak and white oak trees?

  _____

- Continue to explore the panels in this area. Visit "How Are Oaks Adapted to Such a Variety of Habitats?" How have oaks adapted over time in their appearance, shape, or size, based on the available conditions?

Give an example:

_____

Extension:

- What is an Herbarium? Learn more about Herbarium records as a plant window from the past and how it drives our understanding of how plants are related today. Help scientists annotate Herbarium specimens in this citizen science website (Notes from Nature)
- Press Releases related to oaks and their importance: American Oaks Share a Common Northern Ancestor, Solving the Mystery of the White Oak,

Follow-up thoughts:

- Why is understanding a species' place in the "Tree of Life" important? What can it help us do?

  _____

- How can it inform conservation decisions?

  _____

- How does it help plan for the future?

  _____

Teacher Supporting Document

Part 1: Find the Fiction. The false statement for each of these sections is highlighted below. Additional supporting reasoning is included in red.

How does a Tree Live?

A. Tree Roots can be as thick as a tree's branches, but cannot be microscopic.
B. Leaves are like the lungs of a tree because most gas exchange occurs here.
C. Tree rings are formed by xylem tissue (a type of vascular tissue in the plant). Trees produce a new layer of xylem each year.

Reasoning/Support for your selection: Some tree roots can be microscopic. Roots underground are intertwined with fungi, microbes, invertebrates, and the roots of other plants. They gather water and nutrients from the soil and store food for the tree. Most tree roots are found in the top eighteen (18) inches of soil where moisture, air, and nutrients are most abundant. Deeper roots gather water well below the surface and help to anchor the tree.

Measuring a Tree's Vital Signs

A. Just like how our bodies contain specialized tissue types (muscle, bone, connective tissue, skin), trees contain a few major tissue types including: leaf, wood, vascular cambium and roots.
B. A Tree Observatory can integrate a number of different types of data to understand how trees use water, respond to environmental change, and allocate resources for timed blooming and bud burst.
C. A sap flow meter can help provide a window into root system dynamics.

Reasoning/Support for your selection: A sap flow meter can help measure the movement of sap within the tree and associate it with different environmental conditions like humidity, soil moisture, and amount of sunlight. Additionally, the tree trunk expands and contracts each day as the pressures inside change and new cells are created and grow. We can connect these daily changes with the health of a tree and identify early signs of stress or decline in tree health.

How Do Scientists Discover New Knowledge (A closer look at Jan Baptista van Helmont)

A. In the 1600s, it was believed by many that trees were a creation of the soil they grew in. Observing that the soil around the tree did not disappear, grew into a question about "what trees are made of" for scientist, Jan Baptista van Helmont.
B. Van Helmont's hypothesis was that trees were made of water, not soil. He tested this hypothesis by conducting a study using 200 pounds of soil and a 5 pound willow tree.
C. Once van Helmont experimented and drew a conclusion about what trees were made of, everyone accepted his results and moved on to learn more about soil.

Reasoning/Support for your selection: Van Helmot's findings were published in 1648 and simulated debate in the scientific community of the day. When other scientists repeated his work, they improved his experimental design by measuring the water added to the soil and exiting the leaves. It became clear that the tree's weight did

not come from measuring water alone. Today, the scientific consensus is that about 95% of trees' mass comes from a gas in the air: carbon dioxide.

How Can We Help Trees Survive in Urban Areas?

A. Diversity of tree species in an ecosystem (urban or natural) helps increase an ecosystem's resilience to disease and disaster.
B. Diversity is only important when you are looking at the types/species of trees, but not the age diversity of an ecosystem.
C. Understanding trees in their natural setting can help us care for trees in an urban setting.

Reasoning/Support for your selection: A diverse forest is a strong forest. Diversity increases the forest's resilience to disease and disaster. History has shown that trees grown in cities and suburbs (collectively called the urban forest) are prone to collapse when they lack a diversity in tree species. Age diversity is equally important in a forest stand or neighborhood block; young trees must be available to take the place of old veterans.

Part Two: Choose Your Own Adventure. Many of the questions in this section are open-ended. However, provided in red, are some guiding thoughts to target key messages or objectives for each section. Additionally, they have been labeled by level. Each section asks students to think critically. However, some of the information is easier to interpret and less conceptual.

Role #1 – Gettin' Dirty – Soil scientists for urban trees - MEDIUM

- Visit any of the "Caring for Urban Trees" panels. Uncover two (2) factors that impact trees in urban settings.
    - Compacted soil, restricted root growth and the flow of water to the roots. Drought is a common stress of urban trees.
    - Girdling Roots: Occurs when the lateral root branches near the trunk and grows around the trunk. This restriction can cause the trunk to snap off. Some species have a greater tendency to form girdling roots and it is not completely stress-related.
    - Encounters with pollution, insects, and diseases are also common. Urban trees are also susceptible to vandalism, construction, or lightning.
    - Improper pruning (i.e. pruning around power lines or structures) can also be a common impact for urban trees.
- Visit the "Addressing the Challenges of Urban Soils" panels. Look at the demonstrations of trees planted under different pavement conditions.
    - What do you observe about the trees and soil conditions planted in these demonstrations?
        - Varied Root Space Experiment (Compaction): six (6) trees planted in different compacted or limited root space availability- from very compacted clay under concrete, to undisturbed soils with no concrete. Trees will grow better and live longer when systems are used to allow for root growth under pavement.

- Available Root Volume Experiment (Space): four (4) plots each with a different amount of available root space. Providing as much space for roots as possible. Smaller species may be a better choice if root space is limited.
- Tree Tolerance of Poor Soil Quality Experiment - pin oaks and red maples struggle more when planted in poor urban soil conditions. However, American elms and bald cypress will do better. Selecting proper tree species suited to the soil type is important. For more information on proper tree selection - review the Tree Selector Tool.

  - What would you predict will change over time with these trees as they grow?
    (See the information above regarding each experiment set-up.) The hypotheses for these experiments is that trees grown with enough available space, in less compacted environments, with a moderate soil quality tolerance, will thrive over their compared plantings.

- True or False: Different species of trees are more adapted to survive in urban environment than other species? Give your reasoning.
  - True - Pin oaks and red maples struggle more when planted in poor urban soil conditions. However, American elms and bald cypress do better. Selecting proper tree species suited to the soil type is important. For more information on proper tree selection - review the Tree Selector Tool.

Follow-up thoughts:

- Why do you think caring for the soils of urban trees is important?

Soil quality, the number of compactions, and other structures near trees can impact their overall health of trees in urban settings. Trees that are under common stress are not only susceptible to fatalities, but can be targets for diseases and pests.

Think about the images of the urban tree plantings that you examined in The Gateway to Tree Science Exhibit. Why do you think caring for these trees is important? What can they provide to the urban ecosystem?

We need trees in urban communities. Trees benefit communities and their inhabitants. Click for more information about the benefits of trees.

Role # 2- Here I Come to Save the Day! – Conservation biologist to protect threatened trees – MEDIUM/HIGH

- Visit "Laying the Groundwork" and find "Why do we study and conserve oaks?" – Give two (2) reasons why oaks are an important group of species to conserve.
  - Oaks are wide-spread. You can find native oak species on five (5) continents, world-wide.

  - In our region, oaks provide critical food, habitat, and shelter for mammals, birds, and insects in forests and urban settings throughout the northern hemisphere.
  - Oaks store more carbon dioxide than any other woody plant genus in the United States and Mexico.
  - In the Chicago region alone, oaks provide more than $2 billion dollars worth of flood control and other water management services.
- Continue to review the panels in this area "Laying the Groundwork." Visit "Why does The Arboretum create *ex situ* Collections?"
  - What is an "ex situ" collection:
    - *Ex situ* means "off site," or a collection outside where the species would occur naturally.
    - Scientists and Arboretum curators travel around the world to find remaining populations of endangered oaks, and bring back seeds to plant here, where we can safeguard the species for future generations.
    - Through *ex situ* collections, arboreta and botanical gardens can prevent species extinctions, enable scientists to study rare plants, and serve as living genetic repositories for plant species that cannot be stored in conventional seed banks – such as oaks.
- Continue to review the panels in this area "Laying the Groundwork." Visit "How does The Arboretum choose which trees to collect and preserve?"
  - Describe how creating "*ex situ*" collections help ensure that human impact on biodiversity does not cause extinction?
    - *Ex situ* collections are valuable for conservation when they are genetically diverse. This means that they represent a lot of traits for a species within the specimens collected. Genetic diversity helps the species avoid inbreeding, survive environmental challenges, and fight off pests and diseases.
    - Comparing the genetic diversity found in the wild versus the level of genetic diversity in the collection helps determine which species need more seeds collected.
    - Studying natural populations of species also helps scientists understand why they are threatened and how we can help them.

Follow-up Thoughts:

- Why is it important to conserve different species of trees?
  Conserving different species of trees means we are able to protect a wide array of species that are beneficial. Trees provide a number of benefits from medicine to oxygen, and preserving endangered and threatened trees ensures the health of our ecosystems.

- What are some ways that humans impact natural populations of trees and can create threats for extinction?
  Habitat fragmentation, loss of habitat, over grazing, inbreeding (when few individuals of a species remain), pollution, deforestation

Role # 3- That's Right, I MAKE Trees. – Tree breeding to combat tree disease and pests. - LOW

- Visit "Cultivating Resilient Trees" and find What is a hybrid?" Make observations about the trees in front of you and behind these panels. Next answer the questions below:
    - How is the process used to create a hybrid different than the simplest way to propagate? Which parts of the tree are being used?
      Propagation is commonly done by cutting a stem and allowing it to regrow roots. Grafting branches is another way to propagate trees. Hybridization occurs naturally, but can also be facilitated by humans by collecting pollen and bringing it to a flower of another specimen. Propagation creates a new specimen by taking an existing piece of a living collection. Hybridization is assisted reproduction and the end product is a new seed.
    - True or False: Hybridization occurs naturally, but humans have also adapted the process to create resilient and beautiful trees.
      True – Hybridization is a natural phenomenon that humans have adapted to create more beautiful and resilient plants.
- Continue to review the panels in this area. Visit "Dutch Elm Disease." What is the name of the hybrid elm, developed at The Morton Arboretum, that has been cultivated to be more resistant to Dutch Elm Disease?
  Accolade Elm
- Continue to review the panels in this area. Visit the various tree pest and diseases panels (cedar-apple rust, apple scab, Japanese beetles, sycamore anthracnose, emerald ash borer). Record one (1) thing you learned about these threats to tree health:
    - Dutch Elm Disease - This disease is transmitted by female elm bark beetles. These beetles carry the fungus on their bodies and when they feed on the twigs of elm trees, they introduce the fungus to the branches. Once the tree begins to show symptoms, the beetle returns and tunnels under the tree bark to lay eggs. Feeding larvae create galleries/tunnels in the trees phloem (defined: vascular tissue that transports sugar and nutrients to the tree). This disease impacts the vascular tissue of the plant and can interrupt water and nutrient transportation.
    - Cedar-Apple Rust - The cedar rust fungus requires two (2) hosts: a juniper and an apple tree (crab apple tree or Hawthorne). The rust fungus can produce spores each year and these spores form galls on junipers. During spring rains the galls produce a jelly-like tendril that releases wind-carried spores, which move back to the apple host.
    - Apple Scab - Fungal spores are produced on the leaves. These spores overwinter on the ground and expel into the air following rainfall in the spring. The spores are capable of causing an infection for the tree during bud break.
    - Japanese Beetle - This insect is a defoliator. This means it eats the leaf tissue, leaving behind a chewed net of veins. This threatens the trees' ability to photosynthesize if too many leaves are defoliated.

- Sycamore Anthracnose - Sycamore anthracnose is a fungal disease. This can cause leaf drop, twig dieback, or cankers. The disease can also impact new tree growth. The fungus overwinters in diseased fallen leaves and infected branches. Spores are produced in the spring and spread by wind and rain.
- Emerald Ash Borer- An invasive pest that impacts the cambium of ash trees. The insect completes its life cycle within the tree tissue. Adults deposit eggs in bark crevices. The eggs hatch in the trunk and feed on this vascular tissue until they emerge as adults. They create D-Shaped holes when they emerge.

Follow-up Thoughts:

- Why are creating hybrids and cultivating new trees important to long term biodiversity and conservation?
  Researchers work to cultivate trees that are resistant to pests and diseases, though never completely immune to insect pests and diseases. If there is a high level of diversity of trees in a given area, the impact of pests and diseases can be reduced as not all of the trees will die. Long term: cultivating trees and creating hybrids helps conserve different traits and gene flow within species and families.

- Think about ways humans may impact the spread of invasive pests. Record your thoughts below.
  - Moving firewood from one region to another.
  - Lack of proper inspections of foreign wood at ports of entry.

Role # 4- It's All in the Family - Research scientist in plant systematics to understand how species are related to inform conservation. - HIGH

- Visit "Laying the Groundwork" and find "How Are Different Oak Species Related and Why Does It Matter?" What is a phylogenetic tree? What does the Oak Tree of Life tell us?
  A phylogenetic tree, sometimes called a tree of life or family tree, represents our best understanding of the evolution of a given grouping or tree family. The genus Quercus is featured in this tree of life. The oak (*Quercus*) tree of life/phylogenetic tree combines the insights of a global team of plant and biodiversity scientists who integrate research in taxonomy, genomics, ecology, and paleobotany.

  The Oak Tree of Life can help us to understand basic questions in oak biodiversity: How many species are there? Where do they live? How does diversity arise in the first place?

- Continue to explore the panels in this area. Visit the stone patio, which is a visual representation of the Oak Tree of Life. What did you learn about the relationship between red oak and white oak trees?
  The red oaks of Mexico, southern U.S, and Central America form a single lineage. The red oak lineage arose about the same time as the white oaks in this region and they diversified. White oaks were able to survive in drier habitats than that of red oaks.

- Continue to explore the panels in this area. Visit "How Are Oaks Adapted to Such a Variety of Habitats?" How have oaks adapted over time in their appearance, shape, or size, based on the available conditions? Give an example:

  Oaks in this region often exist in savannahs or on prairie edges. They are found in more open woodlands where they can find enough light for their seedlings. Some oak species are shrub-like and grow in dry areas of Mexico and the arid southwestern sections of the United States. They have smaller leaves and can conserve moisture. Oaks in East Asian evergreen forests are tall and majestic. This allows them to compete for light, air, and wind (for pollination) in a dense forest.

  Follow up thoughts:

  - Why is understanding a species' place in the "Tree of Life" important? What can it help us do?
    We can't conserve or understand trees if we don't know who or what they are, where they live, and how they came into existence.

  - How can it inform conservation decisions?
    By understanding how trees are adapted to certain environments, we can be smart in how we plant and protect trees and their habitats.

  - How does it help plan for the future?
    Understanding how oaks adapted to a wide range of environments helps us understand how they will respond to climate in the future. As climate shifts, over time, trees may respond by migrating to new areas or evolving in place.