Unifying Life: Placing urban tree diversity in an evolutionary context

NSF Grant # 1221188

Learning Goals in Five Categories:

1: Noticing

A. Recognize what they know and some of what they may have to learn about plants (i.e. they will recognize their own plant blindness).
B. Understand that careful **observation** is required to notice characteristics that are useful in identifying trees.
C. **Characteristics** that **vary** between trees like **leaf type, leaf margin, leaf arrangement** along a branch**, fruits, tree bark** and **flowers.**
D. Similarities and differences amongst trees:
    i. Most trees **lose leaves** in **winter.**
    ii. Most trees f**lower** at varying times in the **spring.**
    iii. Trees have **fruits, structures that hold seeds,** in the fall.
    iv. Many **fruits form** at varying times in the spring (and summer) **from flowers.** These fruits often stay on the tree through the fall.

2: Identifying

A. Use the Leafsnap app or a field guide to identify trees.
B. Use a set of different **characteristics** that **vary** between trees **like leaf type, leaf margin, leaf arrangement** along a branch**, fruits, tree bark** and **flowers** to justify to their classmates their identification of local street trees**.**

3: Group

A. Use a set of different **characteristics** that are **shared** between trees **like leaf type, leaf margin, leaf arrangement** along a branch**, fruits, tree bark** and **flowers** to group plants**.**

4: Organisms Are A Reflection of Their Evolutionary History (Their Ancestry)

A. These plant **characteristics** like leaf type, leaf margin, leaf arrangement along a branch, fruits, tree bark and flowers can be used to **group** plants because they **reflect** an organism's **ancestry**.
B. This means that plants that **share** these **characteristics** are considered to be **related.**
C. Plants that are closely **related** to one another **share** a recent common **ancestor.**
D. The recent common **ancesto**r will likely have the **same characteristics** that are shared by the **related plants** that are living **today.**
E. These common characteristics are **inherited** from one generation to the next.
F. In fact, characteristics of plants that are alive today exist because they are **inherited** from **ancestors** that lived **long ago,** millions of years ago (e.g. all oak trees have acorns because they were passed down from generation to generation from an ancestor to oaks that lived millions of years ago to oaks that live today). **All living things contain features that make them living representatives of the distant past.**
G. There are small **changes** that **occur over time** which account for the **differences** that are seen between species.

H. **Traits are a reflection of ancestry**. Traits that are adaptations take different form depending upon the group to which an organism belongs.
I. These traits **cannot change** based simply on **short-term need.** There is a limit to how much plant characteristics can change.

5. Appreciation

A. Noticing local street trees
B. Identifying local street trees (knowing)
C. Using the app or a field guide
D. Going outdoors

This curriculum meets the following Next Generation Science Standards:

Disciplinary Core Ideas	
MS-LS1-4.	Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.
MS-LS1-5.	Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
MS-LS4-2.	Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.
Crosscutting Concepts	
Patterns	Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.
Structure and Function	The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.
Science and Engineering Practices	
Practice 1	Asking questions that arise from careful observation of phenomena
Practice 4	Analyzing and interpreting data
Practice 6	Constructing explanations using models or representations
Practice 7	Engaging in argument from evidence

Curriculum Overview:

Project Goals:
The goal of this project to develop curricular resources built around the Leafsnap iPhone app or a field guide to help foster urban middle school student interest and learning of local biodiversity and the patterns of evolution.

Rationale:
Noticing the diversity of life is the first step to understanding the variation that exists within and between species. Designing curriculum around the Leafsnap iPhone app is a new approach for making learning of biodiversity easy and accessible to students. Focused on the diversity of trees growing in the Northeast and mid-Atlantic states, this app can make visible the previously unnoticed trees that your students pass on a daily basis by giving them the tools to easily identify them (the curriculum has also been adapted to use with a regular field guide). Using the variation within and between species to organize groups and contextualize their common characteristics in evolutionary history is crucial to understanding the seemingly contradictory meanings of biodiversity: the uniqueness of each species as a historical record and the common features that unite all life.

Finally, asking students to make sense of their local tree diversity by identifying patterns of evolution through botanical evidence emphasizes the major dimensions of science described in the new *Framework for K-12 Science Learning* that is the basis of the *Next Generation Science Standards* that will likely be adopted by in many states across the United States.

Student Outcomes: What are we hoping for?

These Leafsnap curricular resources are designed to help students to **notice**, **organize**, **contextualize**, and **appreciate** urban **tree diversity** in an **evolutionary framework**.

Outcome Set 1: We hope that these resources will help students to notice and organize local tree biodiversity, specifically the abilities of students to:

1. **Notice within species variation**
   e.g. variation in size and shape of leaves, fruit, bark, and flower characteristics.
2. **Notice differences and similarities amongst tree species**
   e.g. the leaf, fruit, bark, and flower characters that are different and similar amongst species.
3. **Use those differences to identify different tree species**
   e.g the bark and the leaf arrangement of the London plane differentiates the London plane from the maples
4. **Use those similarities and differences to start organizing species into larger groups**
   e.g. maples, oaks, legumes, rose family.

Outcome Set 2: We hope that these resources will help students to use an evolutionary framework to explain similarities and differences amongst species, specifically the abilities of students to:

1. **Recognize that some of the shared characteristics they discover are the result of shared history** (just as physical traits we share with our family members are evidence of relatedness amongst family members)
   e.g. The observation that all oaks have acorns is evidence that all oak trees are related. We will expand on what it means to be "related" in the context of evolution.

2. **Understand that traits are a reflection of ancestry. Traits that are adaptations take different form depending upon the group to which an organism belongs. Traits cannot change simply based upon short-term need.**
   a. **Different plant groups have similar and different traits that are adaptations that help them to survive and reproduce**
      e.g. all plants have green leaves for photosynthesis; all flowering trees have fruits to disperse their seed; fruits may take different form in different species groups.
   b. **Plants have different forms for the same function. These forms are shaped by an organism's ancestry**
      e.g. all flowering trees have fruits for seed dispersal, but some plants use samaras (maples and ashes), some use acorns (oaks), and some use (pods); all trees have leaves that perform photosynthesis, but leaf form in the same environment varies by species group.
   c. **Traits cannot change based simply on short-term needs** (There is a limit to how much fruits and leaves can change)
      e.g. animal dispersed acorns are too heavy to transform into wind-dispersed winged seeds. If the animals that disperse acorns suddenly disappear, the acorns could not suddenly change into wind-dispersed seeds.

Outcome Set 3: We hope that these resources will increase student motivation to notice, identify, organize, and contextualize local tree species into an evolutionary framework, specifically on student motivation to:

1. Notice within species variation.
2. Notice the differences and similarities amongst street tree species.
3. Use those differences to identify different street tree species.
4. Use those differences and similarities to organize street trees into the larger evolutionary groups to which they belong (activities will provide scaffolding to arrive at this concept).
5. Appreciate the importance of being able to notice, identify, organize, and contextualize tree diversity into an evolutionary framework.

Learning Goals (detailed list):

Students will develop a deeper understanding of the following big ideas. They will be able to:

1. Recognize what they know and some of what they may have to learn about plants (i.e. they will recognize their own plant blindness).
2. Recognize that living things grow and change and that they depend on the environment (water, sun, etc.) for their survival.
3. Use the Leafsnap app or tree guide to **identify** trees.
4. Understand that careful **observation** is required to notice characteristics that are useful in identifying trees.
5. Understand that precise language is necessary for justifying their support of rejection of their tree identification hypotheses.
6. Use a set of different **characteristics** that vary between trees like **leaf type, leaf margin, leaf arrangement along a branch, fruits, tree bark and flowers** to justify to their classmates their **identification** of local street trees.
7. Use tree characteristics like **leaf shape**, **leaf arrangement**, and **fruit type** to determine the small **group** to which certain taxa belong.
8. Only specific **heritable** characteristics are useful for **grouping based upon relatedness**.
9. When organisms are considered to be r**elated** to one another, they are considered to share a **common ancestor** from which they **inherited shared characteristics**. Specifically they will understand that:
    i. The common ancestor to oaks had acorns and catkins for wind dispersal of pollen. All oak tree species that exist today are descendants from an ancestral oak tree with acorns and catkins. They inherited acorns and catkins from their common ancestor.
    ii. The common ancestor to maples had a double samara, lobed pointed opposite leaves. All maple species that exist today are descendants from an ancestral maple with a double samara and lobed pointed opposite leaves. They inherited double samaras and lobed pointed leaves from their common ancestor.
    iii. The common ancestor to legumes had pods for seed dispersal and tube-like flowers. All legumes that exist today are descendants from an ancestral legume that had pods for seed dispersal and tube-like flowers. They inherited pods and tube-like from their common ancestor.
    iv. The common ancestor to members of the rose group had flowers with many petals for insect dispersal of pollen. The members of the rose group that exist today are descendants from an ancestral plant that had flowers with many petals for insect dispersal of pollen. They inherited these flowers from their common ancestor.
10. Use multiple **heritable characteristics** to determine the **group** to which trees belong based on **common ancestry**.
    i. **Fruits** are useful characteristics for determining groups.

   ii. **Leaf arrangement, leaf margin,** and **leaf shape** are also useful.
   iii. **Flower structure** is useful for determining groups.
   iv. Tree **size**, tree **shape,** and being stocked in a grocery store are **NOT useful** - legumes and the rose family contain big, small, edible and inedible plants. (For example, legumes include clover, honeylocust, and peas. The rose family includes strawberries, roses, and callery pear).

11. **Traits are a reflection of ancestry**. Traits that are adaptations take different form depending upon the group to which an organism belongs. Traits cannot change simply based upon short-term need.
   i. Different plant groups have similar and different traits that are **adaptations** that help them to survive and reproduce
   e.g. all flowering trees have fruits to disperse their seed and flowers to disperse pollen.
   ii. Plants have **different forms** for the **same function**
   e.g. fruits (samaras vs. acorns) or flowers (catkins vs. showy flowers) may take different form in different species groups .
   iii. These forms have different tradeoffs
   e.g. samaras help seeds fly far, but seeds have little nutrients to help long term growth; although acorns are high in nutrients, many are eaten by animals and never dispersed.
   e.g. high nutrient investment for few showy flowers versus producing many pollen bearing flowers.
   iv. These forms are **shaped by** an organism's **ancestry**
   e.g. all flowering trees have fruits for seed dispersal. Plants with samaras alive today are descended from ancestors that used samaras for seed dispersal.
   v. Traits **cannot change based simply on short-term need** (There is a limit to how much fruits can change)
   e.g. animal dispersed acorns are too heavy to transform into wind-dispersed winged seeds. If the animals that disperse acorns suddenly disappear, the acorns could not suddenly change into wind-dispersed seeds.
12. Evolutionary **groups** are based upon relatedness, which is based on **heritable** characteristics derived from **common ancestry.**
   i. All oaks are related. They inherited acorns from their ancestor that had acorns.
   ii. All maples are related. They inherited double samaras from their common ancestor that had double samaras.
   iii. All legumes are related. They inherited pods and tube-like petals from their common ancestor that had tube-like petals and pods.
   iv. All plants in the rose group are related. They inherited many large petal flowers from their common ancestor that had many large petal flowers.
13. **Notice** similarities and differences amongst trees.
   i. Most trees **lose leaves** in **winter.**
   ii. Most trees f**lower** at varying times in the **spring.**
   iii. Trees have **fruits, structures that hold seeds,** in the **fall.**
   iv. Many **fruits form** at varying times in the spring (and summer) **from flowers.**
   v. **Flowers** take **different form** depending upon **ancestry.**

vi. **Fruits** take **different form** depending upon **ancestry.**
vii. **Leaves and leaf arrangement** take **different form** depending upon **ancestry.**

14. **Angiosperms,** the taxonomic name for flowering plants, are **most closely related** to one another. They are more closely related to one another than they are to the **gymnosperms**, the taxonomic name for plants with naked seeds. All angiosperms have flowers. All gymnosperms do not. The **common ancestor** to angiosperms **had flowers**. They **inherited** flowers from their common ancestor that had flowers.
15. **Flowers** and **fruits** are **reproductive structures** of angiosperms. **Flowers** are for **pollination** & **fertilization**; **fruits** are for **seed dispersal**. After fertilization, the **flower turns into a fruit**. **All fruits**, including fruits we eat, are **ripened ovaries** of flowers.
    a. Flowers consist of male and female parts for sexual reproduction (some flowers contain only male or female parts).
    b. In pollination, the male pollen is transferred to the female part of the flower (through wind or animal pollination systems).
    c. This leads to fertilization, in which the sperm inside the pollen fertilizes the female ovule that rests inside the ovary.
    d. After fertilization, the ovary ripens into a fruit; the fertilized ovule develops into a seed.
    e. Flowers turn into fruit after fertilization.
    f. Fruits are the ripened ovaries of flowers. They contain seeds & disperse them.

Research Findings in Brief:

After studying these resources in New York City middle school classrooms we learned that before using this curriculum:

1. Many students cannot identify a maple or an oak, although most students can identify an acorn.
2. Students do not have the skills to observe important tree features used to identify trees and evolutionary groups. Instead, students use uninformative characteristics like tree size and shape to differentiate trees.
3. Students do not know that being related means to share common ancestry.
4. Students do not know that flowers form fruits or the details about the fruit's function.

After using the curriculum, we found that students were able to

1. Identify maples and oaks and other street trees.
2. Notice key plant characteristics for identification and grouping such as leaf shape, margin, and arrangement, and tree fruits and flowers. Students were less likely to use size to differentiate trees.
3. Recognize that tree fruits were more important for grouping trees than leaf characteristics.
4. Understand that being related means that organisms share a common ancestor from a long time ago whose traits were passed over generations to their descendants that live today.
5. Fruits hold seeds and are used by the plant for seed dispersal and that fruits are formed from flowers.

Research is still ongoing. As we continue to analyze data, we will learn more about what students learn from using this curriculum.

Lesson 1: Plant Blindness: Why go out to see trees?

Goals:
To access students' prior knowledge about local trees and to engage them in the curriculum.

Resources:
1. Plant Blindness Slide Show (PPT and PDF)
2. Plant Blindness article (http://humanflowerproject.com/index.php/weblog/comments/on_seeing_flowers_are_you_missing_anything/)

Procedures:
1. Use questions as a starting point for a discussion with your students about their prior knowledge about trees. If you are inside, you can use prompts in **Resource 1** to start a discussion.
2. Another excellent place to begin this discussion is outside in the midst of trees or you can also allow students to play the Leafsnap games and ask them questions about game difficulty (was it easy or hard to identify the leaves, fruits, or flowers in the games?) This can lead into a discussion centered on **Resource 1** prompts.
3. You might find that your students do not notice very much about plants. Share the concept of plant blindness with your students in order to show them that their experience is the norm.
    a. Plant Blindness - The failure to notice plant life on a day-to-day basis. Botanists have documented these widespread deficits and have even recorded the failure of many to recognize an assembly of plants as anything beyond a setting for animal interactions.
        i. You can relate this concept to sneakers and electronic devices, topics where students excel in noticing, but where others may be "blind." *Provide a personal example; e.g. "I am car blind. I have no idea what make a car is when I see it."*
        ii. You can distribute this article about plant blindness **(Resource 2).**
            1. Good questions to ask are:
                a. How do you personally define "plant" and "flower"? Relate it to the definition described in this article.
                b. What is the benefit of finding fossilized flowers? What can scientists learn from them?
                c. What is the purpose of a flower in a plant? Do all plants produce flowers? Give examples to support your answer.

Anticipated Outcomes:
- Students will recognize what they know (seasonal changes) and some of what they may have to learn.
- Students will understand what it means to be "plant blind."

Lesson 1.5: What Does It Mean for a Tree to Be Alive?

Goals:
If needed, use this activity prior to the previous introduction, to help students understand the similarities and differences between living and non-living things.

Materials:
1. A variety of fallen leaves
2. Silk leaves
3. Small sprouted sweet potato (optional)

Procedures:
Ask students to describe the similarities and differences between silk plant leaves and real (alive) leaves.

A. How do the leaves look the same? (shape, color, texture)
B. How are the leaves different? (real will turn brown without water, scented or moist if ripped open, more venation).
C. To help with this topic, sprout a sweet potato to see the leaves grow. Things that are alive will grow and change.
D. A good follow up question is to ask students if they have ever eaten anything that is alive. [The answer is yes. The raw plants that they eat are comprised of living cells. This is why lettuce wilts (its cells lose water) and why apples are juicy. Their living cells still contain water and the cells that give the plants their form are still undergoing respiration – they are still living.]

Anticipated Outcomes:
- Students will recognize that living things grow and change and that they interact with the environment (water, sun, exchange gases) for their survival.

Lesson 2: Orient students to the Leafsnap app

NOTE: Skip this lesson, if you do not have access to the Leafsnap app.

Goals:

To familiarize students with the Leafsnap app in order to get them excited about using it to identify trees outside.

Materials:

1. iPod touch or iPad devices with Leafsnap loaded and an internet connection.
2. Leaves from nearby trees (at least 1 leaf/device) Good candidate leaves to photograph are gingko, London plane, and Norway maple.

Procedures:

1. Prior to iPod touch or iPad distribution, devise a plan with your students to foster responsible student behavior with the devices. Suggestions include:
    a. Ask students to create a set of rules or guidelines to abide by when using the devices. Students can develop rules with a partner and then share out rules. This list of rules that students share out can become the class rules.
    b. Require students to sign out their device below the responsibility guidelines that they developed.
2. Distribute one iPod touch or iPad per every two students or one per student.
3. Bring multiple leaves (at least 1 leaf/device) to the classroom and ask students to photograph a leaf to explore the app. To help with student orientation to the app, you can project your screen to the class.
    a. Students must snap a picture of their leaf against a white background.
    b. The leaf should lie flat in the picture because a raised leaf may affect the pattern recognition software.
4. Students can begin identifying leaves with partners and then compare their identification success with the identification success of other students who are working with the same leaf. A set of instructions for a table of four is:
    a. Pick one of the leaves from your table, and work with your partner to identify it using the Leafsnap app.
    b. When you have a tree identified, write the name next to the leaf.
    c. After both pairs at your table are done, see if your pair got the same answer as the other pair at your table. Did they all match?
    d. How confident are you in the leaves Leafsnap identified? Do you think Leafsnap correctly identified the tree from which your leaf came?
    e. What can you could do to confirm or reject the tree identification hypothesis?
    f. When you used the app, what else did you learn about the trees? *(Fruits, flowers, leaf arrangement, tree bark, description, scientific and common names)*
    g. How did the app identify the tree? (*pattern recognition software*)

Anticipated Outcomes:

- Students will gain some basic familiarity with the Leafsnap app. They are now ready to go outside to use the app to identify trees.

Lesson 3: Find the Acorn: Observation Skills and Within Species Variation

Goals:
To help students understand the importance of careful observation and precise language for making and communicating scientific claims.

Materials:

1. Use some plant material produced by local trees. Suggestions include**:** honeylocust pods, callery pear fruits, tree leaves, oak acorns, and maple samaras.

Procedures:
NOTE: Acorns are used as an example throughout this activity description, but please substitute with fruits or leaves that you can easily find from common street trees. The above-mentioned fruits should be fairly common in the fall.

1. Form groups of 6-8 students (larger groups are better).
2. **Student Instructions:** Why is it important to make careful observations?
    a. Do Now: Pick one of the acorns from the pile on the table. On an index card, write a description of your acorn.
        - NOTE: Write ONLY on the card. Make sure that you do not make any marks on your acorn!
    b. Put all of the acorns back into the pile in the middle of the table and mix them.
        - Now, find your acorn in the pile.
        - Did you find your acorn?
    c. Now put them all back in the pile again.
        - Trade cards with someone else at your table.
        - See if you can find the acorn that your classmate described. Check with him or her after you find it, so s/he can tell you if it is the correct one.
3. Discussion Questions:
    a. Find the acorn:
        - Was it easier to find your acorn or your partner's? Why?
        - What could have made the hunt for your partner's acorn easier?
        - What skills do you need to succeed at this activity? What would you change if you did it again?
    b. What are some characteristics and skills you will need when examining trees with the Leafsnap app or field guide?

Anticipated Outcomes:
Students learn that:

- Careful **observation** is important to **notice** key variation needed to recognize individual acorns.
- Careful description and **precise language** is required to **justify** and **communicate claims** about the identity of individual acorns and individual trees.

Lesson 4: Put A Name On It: Characteristics for Tree Identification

Goals:
To help students build a set of characteristics to identify trees.

Materials: A variety of:

1. Street tree fruits [Including at least one grocery store fruit. **Save fruits** for lesson 11 and spring lesson 19 (non perishable acorns, pods, and samaras)]
2. Street tree leaves
3. Street tree leaves arranged along a branch (to see leaf arrangement)
4. Optional grocery store fruits if cannot find street tree pods or juicy fruits

Resources:

1. Put a Name on It Worksheet (PPT and PDF)

Procedures:

1. Collect a variety of fruits, leaves, and leaves arranged along a branch
    a. Below is a sample of street trees with easily available fruits.
        i. Oaks (many types of acorns)
        ii. Maples (all samaras)
        iii. Honey locusts, black locust, redbuds, store bought snow peas, green beans (pods)
        iv. Sweetgum (spiky ball)
        v. London plane (ball, not spiky)
        vi. Callery pear, dogwoods, crabapples, store bought apples, oranges, avocado, etc. (fleshy or juicy fruit)
        vii. Ashes (samaras)
        viii. Elms (samaras)
        ix. Lindens (nut like fruit with leafy wing)
        x. Horse chestnut and buckeyes (seed surrounded by hard husk)
        xi. Willow (hairy seed in split open capsule)
2. Label each specimen with a unique letter and distribute around the room.
3. Ask students to use the worksheet **(Resource 1)** to identify the different leaf shapes, arrangements, leaf edges, and fruit types.

Anticipated Outcomes:

- Students will build a set of characteristics to use when describing their trees and when justifying their identification hypotheses. These characteristics include **simple/compound leaf**, **leaf arrangement**, **leaf margin** characteristics, and **fruit** type.

Lesson 5: Students Collect Evidence to Support or Reject Their Tree Identification Hypothesis

Goals:
For students to use the set of characteristics that they developed in the "*Put a Name on It*" activity from Lesson 4 along with the evidence in the Leafsnap app or field guide to support or reject their Tree ID hypothesis.

Resources:
These resources are intended for use with a field guide.

1. 5a Evidence for Tree ID Hypothesis Field Guide (Word and PDF)
2. 5a Evidence for Tree ID Hypothesis Field Guide Teacher Key (Word and PDF)

These resources are intended for use with the Leafsnap app.

3. 5b Evidence for Tree ID Hypothesis Leafsnap (Word and PDF)
4. 5b Evidence for Tree ID Hypothesis Leafsnap Teacher Key (Word and PDF)

Procedures:
Invite students to consider *their role* in tree identification. It is terrific to have Leafsnap to help, but how can WE decide which Leafsnap choice is the best one? If students are using a field guide, review the characteristics they must consider when identifying their trees (leaf type, simple or compound; leaf arrangement, alternate or opposite; leaf margin, smoothed or toothed; fruit type)

1. Working in groups of two, students will visit street or park trees outside your school and use the Leafsnap app to photograph tree leaves. They will upload their photos to the Leafsnap database for Leafsnap to propose a species ID based upon the pattern of the uploaded leaf. If they are using a field guide, students will need to use the field guide key system to develop a tree ID hypothesis.
2. Use the included worksheet **(Resource 1 or 3)** to ask students to consider the accuracy of Leafsnap's species ID hypothesis or their own hypotheses.
3. After students complete their worksheets, ask them to share the observational data they collect with their classmates to make an argument for or against the Leafsnap tree ID or their own tree ID hypotheses.
4. As a group, the class can determine the tree ID based upon the strength of the displayed evidence. Students will learn from tree ID projects other than their own.
5. Following their initial tree ID investigation, students will more extensively explore their local street and park tree diversity to build up a "collection" of identified neighborhood trees.

Anticipated Outcomes:

- Students will identify and justify to their classmates their identifications of local street trees using the **fruit, leaf**, **leaf arrangement,** and **bark evidence** in the Leafsnap database or field guide along with photos of the street tree of interest.
- Students will build a collection of identified trees to use in the following lesson.

Lesson 6: Follow a Local Tree: Students Begin Their Tree Notebooks

Goals:
For students to follow a tree for the school year. Following a tree will help students notice:

1. Tree leaves and leaf cycle
2. Fruits as the structures that contain seeds
3. Fruit development from flower
4. Tree flowers
5. Tree buds

Resources:

1. Tree Notebook Student (PPT and PDF)
2. Tree Notebook Teacher (PPT and PDF)

Procedures:

1. Ask students to choose an individual tree near the school or their home to observe. They can record their observations on the tree notebook handout. **(Resource 1)**
    a. To get a large diversity of trees, scout trees around the school to help students pick different ones or encourage them to pick trees near home.
2. Ask students to observe their tree on a monthly basis, so that they can see the tree life cycle. Students will see their trees lose leaves, see leaf and flower buds, and in the spring they will notice flowers and see the flowers transform into fruits.
    a. At this time students should complete the appropriate monthly observation.
    b. If students have fruits to observe, they should examine their tree fruits and record their observations in the appropriate section of the tree notebook.
    c. In this section, students are asked to compare their fruits to different fruits from other trees. The fruits are the structures that contain seeds. If students cannot find fruits on their tree, they can complete this section by describing the fruits as they are presented in the Leafsnap database or in the field guide. The major fruit types they will likely observe are:
        i. Acorns (oak)
        ii. Samaras (maple, ash, elm)
        iii. Pods (honeylocust, black locust, redbud, etc.)
        iv. Spiky ball (sweetgum)
        v. Ball, not spiky (London plane)
        vi. Fleshy or juicy fruit (callery pear, dogwood, crabapple, cherry)
        vii. Nut like fruit with leafy wing (linden)
        viii. Seed surrounded by hard husk (horse chestnut and buckeyes)
        ix. Hairy seed in split open capsule (willow)
3. Trees to consider following: callery pear, cherry, oak (often tall), maple (often tall too). The callery pear and cherry will develop showy flowers in late March or April. The oak will develop catkins in late April/May. Maples, depending upon the species will develop flowers (not very showy) in March or April. Long winters will push back flowering time on plants that flower early, but leave flowering times for other plants unaffected, meaning many trees will be flowering at the same time after long winters.

Tree Notebook Outline:
Pages 1-4: Selecting your tree: Students **describe** their **selected tree** (leaves and fruits) and match evidence with Leafsnap or field guide.

Page 5: Students make a **map** to mark their tree **location**

Pages 7-16: Students begin **monthly observations** for September-June. Make sure students start their spring observations when you begin to notice the appearance of tree flowers. Students may need to observe multiple times in the month to see when their trees flower and green up. It is easy to miss tree flowers on trees with inconspicuous flowers (some easy flowers to miss are oak catkins, ash, maple, and elm flowers)

After monthly tree observations, there is space in the notebook for close-up fruit and flower observations.

Pages 17-18: Students make **fall fruit observations**

Pages 19-20: Students make **spring flower observations**

Page 21-22: Students make **spring flower** to **fruit summary** of observations (including comparing pollen and seed dispersal mechanisms)

Page 23: Students make **seasonal summary** of tree observations

Page 24: Students **record flowering timing** for trees observed by classmates

Page 25-26: Students determine **close relatives** to their tree

Make an electronic notebook instead: You may also choose to create notebooks online. This allows students to take and upload pictures easily. We suggest uploading the Tree Notebook Student PowerPoint to Google Drive and having the students share their notebook with you. Formatting may change.

Anticipated Outcomes:
Students will:

- Identify a tree to follow based upon **fruit, leaf**, and **bark evidence.**
- Amass a record of their **tree's life cycle**, which helps noticing leaves, flowers and fruits.
- Understand that tree characteristics can be used to determine relatedness and **common ancestry**.

Lesson 7: Students Identify Typical Characteristics of Plant Groups: Is my tree a willow, oak, maple or legume?

Goals:
For students to identify characteristics that define groups (i.e. the characteristics that are fixed within a group).

Resources:
1. 7a Is the Willow Oak a Willow or Oak Student (Word and PDF)
2. 7a Is the Willow Oak a Willow or Oak Teacher (Word and PDF)
3. 7b Is the London Plane a Maple Student (Word and PDF)
4. 7b Is the London Plane a Maple Teacher (Word and PDF)
5. 7c Is the Redbud a Legume Student (Word and PDF)
6. 7c Is the Redbud a Legume Teacher (Word and PDF)

Procedures:
1. Distribute worksheets **(Resources 1, 3 and 5)** to pre-defined student groups. Students can all complete worksheets individually or complete one worksheet individually and then share findings with their larger group.
2. There are many worksheet options. They are:
    a. Is the Willow Oak a Willow or an Oak? [This is an interesting question because although the willow oak has leaves that look like willow leaves, they have acorns making them oaks] **(Resource 1)**
    b. Is the London Plane a Maple? [This is an interesting question because London plane and maple leaves look very similar. They have very different fruits and different leaf arrangements, meaning that the London plane is NOT a maple. (Norway maple leaf arrangement image Bernd Hutschenreuther)] **(Resource 3)**
    c. Is the Redbud a Legume? [This is an interesting question because although redbuds have pods, they do not have compound leaves like other street legumes. However, they are in fact legumes because the pod fruit is the defining characteristic of legumes, not leaf type.] **(Resource 5)**
3. NOTE: The second half of the worksheet is not to be completed until after Lesson 10.

Anticipated Outcomes:
Students will understand that:
- **Fruits** are **bette**r for determining **groups** than leaf shape or leaf arrangement.
- The **willow oak** is an **oak** not a willow because it has **acorns, oak fruits**, not hairy seeds in a split-open capsule that are characteristic willow fruits.
- The **London plane** is **NOT** a **maple** because it has a **differen**t **leaf arrangement** and **fruit** than maples.
- The r**edbud** is a **legume** because it has **pods**.

Lesson 8: Plant Group Characteristics Are Inherited: Use the school play scenario below to help students understand that organisms can be categorized under different criteria, but only hereditary characteristics are useful for making groups based upon ancestral relationships

Goals:
For students to learn that **hereditary characteristics** are the only useful characteristics for **grouping** organisms by **common ancestry**. To learn this goal, students will learn that:

a. People make groups for different reasons.
b. Depending upon our grouping goals, different characteristics will be used.
c. If we want to group based upon relationships, then only specific characteristics are useful.
d. Heritable characteristics are the only useful characteristics for determining group based on relatedness.
e. Inherited characteristics show common ancestry in people.

Resources:
Websites with celebrities and their children:

1. http://omg.yahoo.com/photos/celebrity-mini-me-s-slideshow/
2. http://www.hollywoodheavy.com/detail/012988/spitting-image-celebrity-dads-look-alike/

Procedures:

1. Use this scenario as an in-class or homework assignment:
   a. *Your class has worked for two straight months preparing to sing in the holiday show. Each of you has invited parents, grandparents, and siblings to attend your evening performance. Before the big event is set to begin, you look out from the stage into the auditorium. It is packed with people. You begin to get nervous. In order to calm your nerves, you decide to organize all the people into groups.*
   Into what type of groups could you organize people? Based on which characteristics would you define your groups?

   Write a description of your categorization system. Come up with at least four different ways that you could group people. For each group, write the characteristic on which you would base that group. (For example, one way that you might group people would be into males and females. The characteristic that you would use to define that group would be a person's gender.)
2. Discussion: What categories did you make? What characteristics did you use to define your group?
3. This list describes the type of categories students may make. Explore the categories that students make, but then use the family groups to show that only hereditary characteristics can be used for showing how are people are related.

Category	Characteristic	Notes
Attractiveness	Pretty vs. Ugly	How do you define?
Whether person is a parent	Age	
Whether person is a grandparent	Age	
People I know	A person I recognize	
Boys vs. Girls	Gender	
Dress: e.g. types of shoes, clothing color	Depends upon category – Type of shoe worn: Color of clothes	
Whose family is whose?	Sitting near one another **NOTE:** Not heritable, if sitting then use: Appearance, e.g. eye placement, nose, voice, etc.	

4. A summary of potential discussion outcomes with students follows:
    a. The category considered important defines the characteristics used. Clothing color is not useful for determining who is a grandparent. Age is a better characteristic.
    b. Only some characteristics determine if people are in the same family. (Appearance, e.g. placement of eyes, same nose, voice, etc.) Some characteristics are not useful like age and gender.
5. Show images of celebrity families to further explore relatedness. **(Resources 1 & 2)**
6. Ask students the following questions:
    a. How do we know these celebrities are related?
    b. Useful **characteristics** for showing family relationships are inherited. They are **inherited** from a **common ancestor** [e.g. Jayden Smith has father's Will Smith's ears, who inherited them from his father, who inherited them from a parent as well. They share common ancestors (Jayden's **grandparents**).
        i. Ask your students about their own family (*grandfather's nose etc*.)
    c. If you go back in time far enough, common ancestry explains how humans are related to our Hominid ancestors. Just as family members share physical characteristics, all people share characteristics from Hominid ancestors. They are: *Walking upright, large brains, language*

Anticipated Outcomes:
Students will understand that:

- Depending upon our grouping goals, different characteristics are used.
- For groups based upon relatedness, only **inherited** characteristics are useful.
- **Heritable** characteristics show that people in the same family **are related**.
- Heritable characteristics can be used to show that **ALL people** are related (walking upright, large brains, language).

Lesson 9: Plant Characteristics Result from Shared Ancestry: Draw the Face: Predicting the Appearance of the Common Ancestor

Goals:
To understand that descendants look like their ancestors because they inherit characteristics from them and that these characteristics show that all descendants are related to one another.

Resources:
1. 9a Draw the Face Student Handouts (PPT and PDF)
2. 9a Draw the Face Handouts Teacher PPT and PDF)
3. 9b Draw the Face Handout Questions Student (Word and PDF)
4. 9b Draw the Face Handout Questions Teacher (Word and PDF)
5. 9c Draw the Face Plant Overlay (PPT and PDF)

Procedures:
1. Ask students to complete the "Draw the Face" worksheet **(Resource 1).** There are three versions of this worksheet included in Resource 1 for varying levels of difficulty.
2. Ask students to complete the "Draw the Face Questions" worksheet **(Resource 3)**. This worksheet is designed to help students articulate that the presence of the same inherited characteristics in descendants shows that they are related. It also helps them articulate that the common ancestor can be predicted based upon shared characteristics of the descendants.
3. In order to further relate these diagrams back to plants, apply plant characteristics to the diagram in place of the changing shapes **(Resource 5).**
4. From this activity, students surmise that the common ancestor to all plants that lived millions of years ago was green and had cells. Furthermore, it shows that all plants with leaves share a common ancestor that had leaves. They are more closely related to one another than plants that do not have leaves (like moss).

Anticipated Outcomes:
Students will understand that:
- **Inherited characteristics** show how **descendants are related** to one another
    - In circles
    - In plants
- **Descendant species share common ancestors** that changed over millions of years.
- **Common ancestors** can be **predicted** based upon **shared characteristics**.

Lesson 10: Revisit Lesson 7: Students Identify Typical Characteristics of Plant Groups to explore the common ancestry in trees.

Goals:
For students to learn that the characteristics that define groups reflect that **all members** of the **group are descendants** from the **same common ancestor**.

Resources:
NOTE: These resources can be found in Lesson 7. (Students should already have them.)

1. 7a Is the Willow Oak a Willow or Oak Student (Word and PDF)
2. 7a Is the Willow Oak a Willow or Oak Teacher (Word and PDF)
3. 7b Is the London Plane a Maple Student (Word and PDF)
4. 7b Is the London Plane a Maple Teacher (Word and PDF)
5. 7c Is the Redbud a Legume Student (Word and PDF)
6. 7c Is the Redbud a Legume Teacher (Word and PDF)

Procedures:
NOTE: These are the first diagrams that students see that look like tree diagrams. This format will be used for the rest of the curriculum to show relatedness.

1. Revisit the Lesson 7 worksheets to explore the theme of common ancestry in trees.
2. In this revisiting section, students must characterize the traits of the common ancestor to oaks. They learn that the **oak common ancestor** must have had **acorn** fruits and **alternate leaves**, since all oaks have them **(Resource 1).**
3. Students do the same for the ancestor to maples. The **maple common ancestor** had double **samaras** and **opposite leaves**, since all maples have them **(Resource 3).**
4. Students do the same for the ancestor to legumes. The **legume common ancestor** had **pod** fruits and **alternate leaves**, since all legumes have them **(Resource 5).** **NOTE:** It is unclear whether it had simple or compound leaves. Further Information: *Option 1: The ancestor to all legumes had simple leaves. Compound leaves evolved secondarily and all legumes with compound leaves share a more recent common ancestor than legumes that have simple leaves. Option 2: The ancestor to the legumes had compound leaves and the redbud lost the ability to make compound leaves. This is the scenario favored by scientists after DNA analysis showed that the DNA of the legumes with simple leaves had more in common with legumes with compound leaves than they do with the few legume species with simple leaves. (simple leaf legumes were found nested within the compound leaf legume).*

Anticipated Outcomes: Students will understand that defining **group characteristics** are based on **common ancestry**:

- The common ancestor to oaks had acorns and alternate leaves. All oak trees today are descendants from an ancestral oak tree with acorns and alternate leaves.
- The common ancestor to maples had a double samara, lobed pointed, opposite leaves. All maples today are descendants from an ancestral maple with double samaras and lobed pointed, opposite leaves.
- The common ancestor to legumes had pods for seed dispersal. All legumes today are descendants from an ancestral legume that had pods for seed dispersal.

Lesson 11: Fruit, Reproductive Structures, Are Formed From Flowers

Goals:
To help students understand that:

- Fruits are reproductive structures with seeds in both street and store bought fruits.
- Fruits help in seed dispersal.
- There are a variety of ways fruits help plants disperse their seeds.
- Fruits are formed from flowers.

Materials:

1. A variety of fruits from street trees (accumulate fruits daily; **save** for spring lesson 19.
2. A variety of fruit from the grocery story

Resources:

1. Fruit Dissection Worksheet (PPT and PDF)
2. Fruit Dissection Worksheet Teacher (PPT and PDF)
3. Mcintosh Flower to Fruit: http://www.botany.org/bsa/misc/mcintosh/mcintosh.html

Procedures:

1. Students use the Fruit Dissection Worksheet (**Resource 1**) to guide street and store bought fruit dissections to learn that **ALL fruits,** including **street and store bought** fruits (inedible and edible) have **seeds** that are used for dispersal and that fruits take different forms depending upon their dispersal mechanism. **NOTE:** Questions 1 through 4 on the last page should be answered in this activity. Questions 5 and 6 will be completed in the flowers form fruit activity described in bullet point two.
    a. The major fruit types they will dissect are:
        i. Pods (black locust, honeylocust, redbud and store bought pods like snow peas, snap peas, green beans, tamarind, etc.
        ii. Samaras (tree of heaven, maples, ashes, elms)
        iii. Fleshy or juicy fruit (callery pear, cherry and all almost all store bought fruits like cucumbers, oranges, squash, lemons, etc.)
        iv. Acorns (oaks) and store bought nuts like chestnuts and hazelnuts
        v. Ball not spiky (London plane)
        vi. Spiky Ball (sweetgum)
        vii. Seed surrounded by hard husk (buckeyes and horse chestnuts- different than edible chestnuts)
        viii. Hairy seed in split open capsule (willow)
        ix. Nut like fruit with leafy wing (lindens)
    b. Discuss the similarities and differences amongst fruits. The take home is:
        i. That **all fruits**, although they may look differently, contain **seeds**.
        ii. That different containers are used for different types of seed dispersal.
        iii. Different **methods** of seed **dispersal** have **strengths** and **weaknesses**.
            1. **Pods:** Strength: They burst to eject seeds far; Weakness: Many do not germinate.

2. **Samaras:** Strength: Many seeds fly far (low investment per seed); Weakness: Many seeds do not land in appropriate locations for germination; seed is small, so less stored nutrients.
3. **Acorns:** Strength: Animals will eat fruit and disperse great distances and the seed will have nutrients to help it grow; Weakness: Large investment per seed, meaning the tree puts a lot of resources into each acorn. Like putting all eggs (seeds) in one basket, but making the basket (whole acorn) very strong.
4. **Fleshy or Juicy Fruits:** Strength: Animals eat fruit and disperse it great distances. Weaknesses: Very large investment, meaning the plant expends extra energy making the fleshy material, even though these nutrients will not help the seed to grow.

2. Flowers Form Fruits:

a. Ask students containing seeds is related to reproduction.
b. Ask students about other plant structures (flowers) that relate to reproduction. Remind them of "the birds and the bees" if they don't remember.
c. How are flower and fruit reproductive structures connected? To answer this question, ask students to use the **McIntosh apple development** resource **(Resource 3)** to discover how fruits are connected to flowers. The resource shows how the **female ovaries** at the base of the pistil **develop into fruit** and how the **ovules** that are inside them **develop into seeds.** Students can now complete questions 5 and 6 on the last page of the Fruit Dissection Worksheet **(Resource 1)**.
    i. Fruits are in fact the ripened ovaries flowers and seeds are the fertilized ovules. Fruits are only made once the flower is pollinated.
    ii. When students eat fruit, they are eating the ripened ovaries of the flower!
    iii. In the spring, students will observe their tree for signs of their tree's flowers turning into fruits. Careful observation will show that the fruit appears in the same spot as the flower once was. (The maples and the callery pear show this pattern very clearly. Oaks do not, since the catkins are male flowers. The female flowers are very small and develop into acorns).

Anticipated Outcomes:

Students will understand that:

1. All **fruits** are the reproductive structures that **contain seeds**.
2. **ALL store-bought fruit and tree fruits (edible and inedible) are the same. They are all fruits.**
3. Fruits help in **seed dispersal**.
4. There are a variety of ways fruits help plants disperse their seeds.
5. Plants can use similar strategies for pollen and seed dispersal (wind and animals).
6. **Fruits are formed from flowers.** They are the **ripened flower ovaries**.

Lesson 12: Evolutionary Constraint: Students compare fruits (acorns and samaras) from different tree species and see that one fruit type cannot just turn into another type based upon need

Goals:
For students to learn that adaptations take different forms depending on the group to which an organism belongs. These **adaptations reflect a group's ancestry**. They cannot change based simply on short-term need (i.e. over a few generations). These kinds of changes, if they occur at all, can **take millions of years**.

Resources:
1. Acorns vs. Samaras Student (Word and PDF)
2. Acorns vs. Samaras Teacher (Word and PDF)

Procedures:
1. Ask students to use the "Acorn vs. Samara" worksheet **(Resource 1)** to determine the similarities and differences between acorns and samaras.
2. Ask students to lift up and drop their fruits to closely examine them.
3. Discuss with students key worksheet ideas:
    a. Similarities: Samaras and acorns have the same function: seed dispersal.
    b. Different: Dispersal strategies and form: samara-light/wind; acorn-heavy/animals.
    c. Acorns cannot change form to be like samaras if their animal dispersers disappear. Too many changes would be required (not enough variation for selection). If animal dispersers suddenly disappear, oaks would go extinct.
    d. This is called **historic constraint:** Change only happens within the **limits of** an **organism's variation**, which is **based on** what it inherited from its **ancestors**.
    e. Examples of historic constraint are: The **QWERTY keyboard**: Named for the top letters on the left-hand side of the keyboard, it was designed to make typing faster, by preventing mechanical typewriters from jamming at high speeds. However, recent evidence shows that the layout may have been influenced by the needs of telegraph operators, who requested letters with similar Morse code to be placed next to each other (e.g. S and Z near each other). Either way, new keyboard configurations would improve typing speed today. Yet, the old keyboard layout remains because people know how to type with this keyboard design, making the barrier to adaptation of a new design too high. The **extra tiny pocket on a pocket in jeans** was designed for a watch. Although not needed, it is now a design people like.

Anticipated Outcomes: Students will understand that
- **Traits** are a **reflection** of **ancestry**.
- **Adaptations** take **different** form depending on **evolutionary group**.
- **Historic constraint** means that **change** only happens **within** the **limits** of an **organism's variation.**
- Organisms will go **extinc**t if the environment **changes quickly**. Evolution occurs too slowly (millions of years) to quickly respond to sudden environmental changes.

Lesson 13: Tree Sort: Students Use Characteristics Based Upon Common Ancestry to Group Most Closely Related Trees: Fruits Show Ancestry

Goals:
For students to use the characteristics they used to identify willows, oaks, maples, and legumes in Lesson 7 to make tree groups of plants that are most closely related (e.g. maples together, oaks together, legumes together).

Resources:
1. 13a Fall Sorting Cards (PPT and PDF)
2. 13b Name That Group Student (Word and PDF)
3. 13b Name That Group Teacher (Word and PDF)
4. 13c Common Ancestor Group Student (Word and PDF)
5. 13c Common Ancestor Group Teacher (Word and PDF)

Procedures:
1. Ask students to organize the trees on the supplied sets of tree images into groups based upon leaf shape, leaf arrangement, and fruit characteristics that they used to identify them.
    a. Make color copies of **Resource 1**. Each slide can be cut into 4 separate cards. Laminate for longer life. Each student group will require one class set.
2. Ask students to use the Name That Group worksheet **(Resource 2)** to divide the trees into 6 groups based on characteristics that indicate shared ancestry (if you use 6 groups, you will need to make 6 sets of cards).
    a. The tree sorting cards contain fruits, leaf arrangement, leaf shape, and a picture of the whole tree. The most useful characteristics will be the fruits for making groups, but other characteristics might also be indicative of groupings.
    b. The plants can be differentiated from one another by their **fruits**:
        i. Ashes have single thin and flat samara
        ii. Buckeyes & horsechestnuts have a seed surrounded by a hard husk
        iii. Legumes have pods
        iv. Oaks have acorns
        v. Maples have double samaras
        vi. Willows have a hairy seed in a split open capsule
    c. They often can be differentiated by their **leaves**
        i. Ashes have compound opposite leaves
        ii. Buckeyes & horsechestnuts have palmately compound leaves that are opposite
        iii. Legumes often have smooth compound, always have alternate leaves
        iv. Most oaks have lobed leaves that are alternate
        v. Maples have pointed lobes leaves that are opposite
        vi. Willow often have long thin toothed leaves that are alternate
3. The worksheet asks students to consider which characteristics they used to make groups. The students will notice that leaf shape, margin, and arrangement are informative. They will also see that fruits are informative. It will be apparent that size

and shape of the whole tree is NOT informative. For example, sand ticktrefoil, a tiny plant, is grouped with other legumes including large trees like honey locusts.

4. Ask students to complete the Common Ancestor worksheet **(Resource 4)** to predict the appearance of the common ancestor of each of their defined groups. The students will make their predictions on small tree diagrams. Students will learn that:
    a. The shared characteristics that define the groups were present in the **common ancestor** to that group (e.g. the common ancestor to **oaks had** acorns and alternately arranged leaves; the common ancestor to **maples had** pointy lobed opposite leaves with a double samara fruit; the common ancestor to **legumes had** pods and alternately arranged leaves; the common ancestor to **ashes had** a single samara fruit and compound opposite leaves; the common ancestor to **buckeyes** and **horse-chestnut had** opposite palmately compound leaves and fruits with husks; the common ancestor to **willows had** long thin toothed leaves that are alternate and hairy seeds in a split open capsule).
    b. The presence in the common ancestor is the reason why the characteristics are present today and shows how **plants alive today retain characteristics from their ancestors that lived long ago**.

Anticipated Outcomes: Students will be able to:

- Make and justify several simple groups like the ones mentioned above. These are:
    - **Oaks** together based upon leaf shape and **acorns**.
    - **Maples** and box elder together based upon leaf shape & **double samara**.
    - **Legumes** together based upon the **pods** (locusts, catalpa, redbud).
    - **Ashes** together based upon the single **samara**, **compound opposite leaf**.
    - **Buckeyes** & **horsechestnuts** together based upon opposite **palmately compound** leaf & **fruit**.
    - **Willows** based upon long thin toothed leaves that are alternate and having hairy seeds in a split open capsule **fruit**.
- Notice that:
    - **Fruits** are **informative** for showing **relationships**.
    - Leaf shape, margins, and arrangement are informative for showing relationships.
    - **Size** and shape of whole are **Not Informative** for showing relationships.
- Understand that **relationships** are **based** upon **common ancestry**. The common ancestor to:
    - Oaks had acorns fruits and alternately arranged leaves.
    - Maples had pointy lobed opposite leaves with a double samara fruit.
    - Legumes had pods and alternately arranged leaves (locusts, catalpa, redbud).
    - Ashes had a single samara fruit and compound opposite leaves.
    - Buckeyes and horse-chestnut had opposite palmately compound leaves and fruits with husks.
    - Willows had long, thin, toothed leaves that are alternate and hairy seeds in a split open capsule.

Lesson 14: Summary of Fall Curriculum: Tree Characteristics Like Fruits Reflect Evolutionary History

Goals:
To summarize the major activities and learning of the fall.

Resources:
1. Wrapping It Up Student (Word and PDF)
2. Wrapping It Up Teacher (Word and PDF)

Procedures:
1. Ask students to complete the Wrapping it Up worksheet **(Resource 1)** to wrap up the big ideas from this fall unit. This worksheet can be used as an exam.
2. The worksheet asks about concepts that they learned. They are:
    a. What it means to be **plant blind**.
    b. Using characteristics to **identify trees**. They are:
        i. Leaf shape (simple leaf, lobed simple leaf, compound leaf)
        ii. Leaf edge (smooth, wavy, toothed)
        iii. Leaf arrangement (alternate or opposite)
        iv. Fruit type [acorn, ball-spiky, ball-not spiky, hairy seed in a split open capsule, juicy fruit, nut-like seed with leafy wing, pod, samara, seed (surrounded by a hard husk)]
        v. Other characteristics that they haven't used (e.g. bark and flowers)
    c. Using these same characteristics to **group trees** (fruit has greatest weight).
    d. Understanding that the characteristics that they use to identify and group trees are **inherited from ancestors**. This means that closely related species share a recent common ancestor that had the same features that define the group. For example:
        a. All oak trees share a common ancestor that had acorns. All oaks today have acorns, since they are descended from an ancestor with acorns.
        b. All maples share a common ancestor with opposite leaves and samaras. All maples today have opposite leaves & samaras because they are descended from an ancestor with opposite leaves & samaras.
        c. All legumes share a common ancestor that had pods. All legumes today have pods because they are descended from an ancestor with pods.
    e. Understanding **evolutionary constraint** limits how much trees can change. This limit can lead to extinction if the environment changes too rapidly.
    f. Fruits are seed containing reproductive structures. They are ripened ovaries of flowers. **Supermarket & tree fruits are the same**, except people eat market fruits.
3. Final Take Home: The characteristics that vary amongst trees can be used to identify & group species, and determine the appearance of the ancestor of that group.
4. Remind students to continue to observe trees in notebooks; will continue in spring.

Anticipated Outcomes: To **summarize** the major **themes** of the curriculum and to **alert students** to ongoing tree notebook observations and continued **tree study in the spring**.

Lesson 15: Flower Form: The Structure of the Flower

NOTE: This is the start of the Spring Curriculum. Students should observe trees in their tree notebook throughout the curriculum. It is possible to immediately do the spring unit after the fall unit, but then you must use the images included and not street flowers.

Goals:

To help students understand that:

- Most street trees have flowers, even if they are not pretty.
- All flowers have some or all of these parts: sepals, petals, stamens, and pistils.
- Flowers take different form for similar functions (e.g. wind pollinated versus insect pollinated).

Resources:

1. 15a Ugly Flowers (PPT and PDF)
2. 15b Flower Form Function Student (PPT and PDF)
3. 15b Flower Form Function Teacher (PPT and PDF)

Materials:

1. Animal Pollinated Flowers – any showy flower that is in bloom and/or cut flowers. We recommend callery pear, tulips, alstroemeria, gladiolas, lilies and irises.
    a. **DO NOT USE** daisies, carnations or sunflowers. They are composites and have a complicated flower structure. In addition, you can use these tree flowers listed below.

Animal Pollinated Flowers - Showy and Non-Showy Tree Flowers

1. Magnolia - showy flower (lots of petals; insect pollinated)
2. Callery pear - showy flower (lots of petals; insect pollinated)
3. Cherry - showy flower (lots of petals; insect pollinated)
4. Redbud- showy flowers (lots of petals, insect pollinated)
5. Honeylocust - not showy (but lots of nectar; insect pollinated)
6. Maples - not showy (small petals, small flowers with lots of pollen; wind and insect pollinated)

2. Ugly Flowers for dissection: If you cannot find ugly flowers, use the last slide in **Resource 1**.

1.

Catkins

1. Oaks - lots of stamens, lots of pollen; wind pollinated
2. Birch - lots of stamens, lots of pollen; wind pollinated
3. Willow - lots of stamens, lots of pollen; wind pollinated. Pussy willows can be **purchased** prior to spring. Put in water and they will flower in a few days. You will see the stamens.

Procedures:

1. Use Ugly Flowers (**Resource 1**) to introduce flowers and expand student flower conceptions to include both attractive and unattractive tree flowers. Then introduce the flower dissection to help students understand the parts of both ugly (wind pollinated) and attractive flowers (animal pollinated).
2. Dissect flowers to learn flower structure and function.
    a. Dissect tulips or callery pear first. They contain all flower parts. Then also dissect at least one wind pollinated ugly flower.
    b. Students draw flowers and label parts on Flower Form worksheet **(Resource 2)**.
    c. Display this definition of terms, while they complete this activity:
        i. *Pistil:* Female reproductive organ, consisting of ovary with ovules, a stigma, and usually a style.
        ii. *Stamens*: Male reproductive organ. A thin rod with pollen at the end.
        iii. *Petals*: Colorful leaf-like structures, usually towards outside of flower.
        iv. *Sepals:* Protection for flower in bud and support for petals in bloom
    d. Use worksheet to explore flower function and include a discussion comparing similarities and differences between pollination and seed dispersal mechanisms. Both flowers and fruits have specialized structures for wind or animal dispersal.
        i. Flowers with lots of nectar are insect pollinated.
        ii. Flowers with many stamens are wind pollinated.
        iii. NOTE: Showy flowers will **NOT** cause **allergies.** They do not have light pollen that can go airborne. Flowers that cause allergies are not showy. Their pollen is light and airy to catch the wind.
3. Ask students to complete flower section of their tree notebooks, as trees flower.
4. A similar worksheet is part of each student's tree notebook. Included are sample answers for maples, rose family (callery pear or cherry), oaks, and legumes.

Anticipated Outcomes:

Students will understand that:

1. **Most trees** have **flowers**, even if they are hard to see an **unattractive**.
2. Trees and plants sold as cut flowers both contain flowers that have some or all of these parts: **sepals, petals, stamens, pistils.**
3. Flowers, like fruits, have **different forms for wind or insect pollination**.

Lesson 16: Evolutionary Constraint: Students compare flowers (showy and catkins) from different tree species and see that one flower type cannot just turn into another type based upon need

Goals:
To help students understand that **ancestry shapes form** (oaks have catkins, the pear group has showy flowers), that **form is constrained by ancestry** (catkins and pear flowers can change only so much), that flowers **cannot suddenly change** base on short-term need (showy flowers cannot easily become catkins if they lose their insect pollinators), **change** happens **over long periods of time** (millions of years).

Resources:
1. 16a Catkin and Showy Flower Pictures (PPT and PDF)
2. 16b Catkins and Showy Flowers Student (Word and PDF)
3. 16b Catkins and Showy Flowers Teacher (Word and PDF)

Materials:
1. Catkins (see lesson 15 guide for appropriate catkins).
2. Showy flowers –lesson references callery pear, but any showy flower (except composites) is appropriate

Procedures:
1. Students dissect catkins and showy flowers or use **Resource 1**, catkin and showy flower pictures to complete the Catkin and Showy Flowers worksheet **(Resource 2).**
2. Discuss with your students key worksheet ideas:
    a. Same: Both showy flowers and catkins have the same function – pollination.
    b. Different: They use different strategies to disperse pollen, which affects their form. Showy flowers -nectar/attract insects. Catkins- lots of light pollen/wind.
    f. Showy flowers cannot change their form to be like catkins if the environment suddenly changes so that insects no longer disperse their pollen. Too many changes would be required (not enough variation for selection). If animal pollinators suddenly disappear, oaks would go extinct.
    g. This is called **historic constraint:** Change only happens within the **limits of** an **organism's variation**, which is **based on** what it inherited from its **ancestors**.
    h. Examples of historic constraint are: The **QWERTY keyboard** and the **extra tiny pocket on a pocket in jeans**. Both described in lesson 12 guide.

Anticipated Outcomes: Students will understand that
- **Traits** are a **reflection** of **ancestry**.
- **Adaptations** take **different** form depending on **evolutionary group**.
- **Historic constraint** means that **change** only happens **within** the **limits** of an **organism's variation.**
- Organisms will go **extinc**t if the environment **changes quickly**. Evolution occurs too slowly (millions of years) to respond to such sudden environmental changes quickly.

Lesson 17: Which Plants Belong Together? Cut Flowers and Street Tree Flowers

Goals:
To help students understand that:

- Trees produce flowers just like the plants with cut flowers that they see in the store.
- Some plants with cut flowers (like roses) share more with street trees than they do with other plants with cut flowers (tulips and alstroemeria).

Materials:

1. Callery pear and cherry tree branches with flowers from trees
2. Tulips, alstroemeria, roses from store. Use roses and then two monocot cut flowers with leaves. A plant is a monocot if its leaf veins are parallel. Daffodils are monocots, but are sold without leaves.

Resources:

1. 17a Which Plants Belong Together Pictures (PPT and PDF)
2. 17b Which Plants Belong Together Student (Word and PDF)
3. 17b Which Plants Belong Together Teacher (Word and PDF)

Procedures:
NOTE: Do activity when callery pear and cherry trees bloom. Pear blooms slightly earlier than cherry (usually April).

1. Students examine fresh cut pear and cherry tree branches and store bought tulips, alstroemeria and roses. If you cannot find live specimens use **Resource 1.** It contains an introduction and pictures of all flowers.
2. Distribute Which Plants Belong Together **(Resource 2)** and ask students:
    a. To make and record in their worksheets their initial hypothesis of which plants belong together (2 groups only) and their grouping explanation. Students will likely put make cut flower group and tree flower group based upon size.
    a. To examine plants to support or reject their hypothesis. They will examine:
        i. Leaf edge (Toothed - rose, pear and cherry; Smooth - alstroemeria and tulips)
        ii. Leaf vein pattern [(Net veins - rose, pear and cherry; Parallel venation - alstroemeria and tulips) This is the informative character. It indicates a major difference in plant types (monocot and dicot)]
        iii. Leaf arrangement – all alternate– not an informative characteristic.
        iv. Flowers (Botanists classify and group based on flowers, but students will not have the appropriate skills to do this type of analysis.)
        v. Tree size and shape as a grouping characteristic, after they make groups. Plant **size** and **shape** are **NOT good** indicators of ancestry or group. Roses, although small, do not belong with tulips and alstroemeria, other scut flowers found in the grocery store. Instead, **small roses belong** with **large** callery pear and cherry **trees**.

3. Students may also notice other characteristics like **woody vs. herbaceous** plants (e.g. rose, pear and cherry are woody plants that have above ground perennial stems covered with a thickened bark layer; alstroemeria and tulips are herbaceous plants with leaves and stems that die down at the end of the growing season.)
4. Wrap up: Ask students to compare their prediction of which species are most closely related to what they found when they closely examined their plants. Their predictions most likely grouped the rose with the other cut flowers and not with the trees. Yet the leaf characteristics provide evidence that the **small roses belong with the large street trees and not with the other small cut flowers.**

Anticipated Outcomes:
Students will understand that plants groups based on leaf characteristics like shape, margin, and venation are more meaningful than groups based on plant size. **Size does not indicate relatedness**.

Lesson 18: Ancestry Assessment: Making the connection between plant groups and relatedness

Goals:
To gauge how much students connect related groups to common ancestry.

Resources:
1. What Does it Mean to be Most Closely Related Student (Word and PDF)
2. What Does it Mean to be Most Closely Related Teacher (Word and PDF)

Procedures:
1. Ask student to complete Most Closely Related worksheet in pairs **(Resource 1).**
2. This worksheet helps students consider what it means for roses to be most closely related to cherries and pears and for alstroemeria and tulips to be most closely related to each other. **Leaf venation** (net or parallel) is the major characteristic that defines each group. This characteristic **is evidence of common descent from a shared ancestor.** The pear, cherry, and rose are descended from an ancestor with net veined leaves, and the tulips and alstroemeria are descended from an ancestor with parallel veined leaves. This means that roses, pears, and cherries have net veined leaves because their ancestor had those kinds of leaves. Tulips and alstroemeria have parallel leaves because their ancestor had parallel leaves.
3. Discuss worksheet with students.

Anticipated Outcomes:
Students will understand that:
- **Closely related organisms** share a **more recent common ancestor** than they do with organisms that are not part of that closely related group.
- The **most recent common ancestor** of closely related organisms had the **same characteristics** as the **descendant organisms** (e.g. plants today with net venation shared an ancestor with net venation; plants today with parallel venation shared an ancestor with parallel venation).
- Even if two plant species are not the most closely related, they may still be related and share a common ancestor further back in time (e.g. all the tulips, alstroemerias, roses, cherries, and pears share an ancestor that was green, had leaves, veins, and flowers).
- The structure of a tree diagram. Taxa are grouped together and the characteristics used to group them are marked on the diagram.

Lesson 19: Tree Sort: Students Use Characteristics Based Upon Common Ancestry to Group Most Closely Related Trees: Fruits and Flowers Show Ancestry, Size Does Not

Goals:
For students to understand that:

- Plants can be grouped by flowers and fruits and to a lesser extent leaves.
- Size and plant shape (not leaf shape) are not useful characteristics for grouping based on ancestry or relatedness.
- Herbaceous plants can be grouped with shrubs and trees by their flowers and fruits:
  - Small strawberries, raspberries, and roses are in the same group as trees like pears and cherries (the rose group).
  - Small sand ticktrefoil, peas, and peanuts are in the same group as trees like honey locust and redbud (legumes) based upon their flowers and fruits.

Resources:

1. 19a Name That Group Sorting Cards (PPT and PDF)
2. 19b Name That Group Student (Word and PDF)
3. 19b Name That Group Teacher (Word and PDF)
4. 19c Predicting the Appearance of the Common Ancestor Student (Word and PDF)
5. 19c Predicting the Appearance of the Common Ancestor Teacher (Word and PDF)

Procedures:
NOTE: There are a number of worksheets for this lesson, so you can structure your lesson so that students work on one and then share with the group or class.

1. Remind students that they just grouped a small set of plants based on their leaf characteristics (the tulip/alstroemeria group versus rose/pear/cherry group). Now they will need to examine many plant characteristics to sort a large group of plants.
2. In groups of four to six, students will work with a stack of 24 cards to determine the four groups to which they belong.
    a. Make color copies of **Resource 1**. Each slide can be cut into 4 separate cards. Laminate for longer life. Each student group will require one class set.
    b. Ask students to complete the accompanying Name That Group worksheet **(Resource 2).**
    c. Do not tell students the names of the different groups, just ask them to use the information on the cards to explain reasoning and arrange plants into the groups that they think are most closely related. There will be a total of four groups.
    d. These are the **groups** in the stack:
        i. **Rose** family: includes strawberries, raspberries, roses, cherries, pears, and hawthorns.
        ii. **Legumes**: includes sand ticktrefoil, peas, Chinese scholar tree, redbud, black locust, yellowwood.

   iii. **Oaks:** includes live oak, white oak, willow oak, red oak, pin oak, black oak, scarlet oak.
   iv. **Maples:** includes Norway maple, red maple, Japanese maple, sugar maple, paperbark maple.
3. Ask students to name easy to identify plants and name plants for easier discussion.
4. Ask students to share out the groups that they made and their reasoning. The major groups and justifications are:
   a. The Rose group – fruit form and many petaled flowers
   b. Legumes – pod fruit and tube like flower
   c. Oaks – acorns and flowers in catkins
   d. Maples – samaras and flowers with reduced petals and large stamens
5. You will likely to need to review names of fruits (pods, acorns, samaras fleshy or juicy fruits) for discussion of justification. Bring in saved fall fruits to help students.
6. Discuss the most and least useful characteristics.
   a. **Most useful: Fruits** – pods, acorns, fleshy fruits, samaras; **Flowers** – many petals, fused petals, reduced petals, catkins (no petals)
   b. **Not Useful: Size** – because all the small plants do not belong together; Leaf arrangement – because only useful for differentiating opposite leaves of maple.
7. Students then complete Predicting the Appearance of the Common Ancestor worksheet **(Resource 4).** They can divide up tasks and share findings.

Anticipated Outcomes:
Students will understand that:

- Plants groups based on leaves fruits and flowers are more meaningful than groups based on size. **Size does not indicate relatedness** (e.g. Large pear and hawthorn trees share more with small raspberries and strawberries than with other trees; Large pod trees share more with small pod plants like pea plants than with other trees).
- Most recent common ancestor of the rose group had characteristic showy flowers; legume group had pods; maple group had samaras, oaks had acorns and catkins.
- **Animals** can also be **grouped** by **common ancestry**.
- Many of the **characteristics of organisms today exist** because they **arose** in their **ancestors** that **lived a long time ago** (e.g. people have backbones because we descended from an ancestor with backbones).
- Tree diagrams can be used to show how organisms are related to one another in a nested or hierarchical manner.

Lesson 20: Flowers, Flowers Everywhere

Goals:
To help students notice the timing of street tree flowering.

Resources:
1. Tree Notebook Student (PPT and PDF; found in Lesson 6)
2. Tree Notebook Teacher (PPT and PDF; found in Lesson 6)

Procedures:
NOTE: Ideally, this lesson falls here, but based on flower timing, you may need to move it around.
1. Now that the students have mostly completed their tree notebooks, they can compare flowering time of different trees.
2. In the back of the tree notebook on page 24, ask students to tabulate the data their classmates collected on tree flowering times. These are estimated dates of when trees should begin to flower. Flowering times vary considerably from year to year and long winters will push back flowering times, especially for the early flowering trees:
    i. Silver maple (mid-March or earlier)
    ii. Norway maple (mid-March)
    iii. Magnolia (early to mid March – early April)
    iv. Callery pear (mid-late March-early April)
    v. Cherry (early April)
    vi. Pin oak (April – May)
    vii. Honeylocust (May)
3. Students answer questions comparing flowering time between different trees.

Anticipated Outcomes:
Students will understand that:
1. Most street trees flower.
2. Street **trees flower** at **different times**.
3. Street tree flowers take different forms.
4. Many street trees flower before leaves appear on trees.

Lesson 21: Unifying Trees: The Two Great Groups of Trees - Trees With Flowers Are Angiosperms; Trees With Cones Are Gymnosperms

Goals:
To help students understand that:

1. All plants with **flowers and fruits** are related and called **angiosperms** (flowering plants). They all share a common ancestor that had flowers and fruits.
2. All plants with flowers have seeds that develop inside a fruit (flowers to fruit).
3. All plants that **hold seeds on cones** are related and called **gymnosperms** (means *naked seed*). These plants do not have flowers or fruits, which develop from flowers.
4. All street trees are either angiosperms or gymnosperms. They are related because they share a **common ancestor** with **seeds**.
5. Angiosperms & gymnosperms share leaf and green pigment structures with other vascular plants like **ferns**. They share a common ancestor that had **leaves** & was **green**.
6. Plants cannot transform their structures based simply on need (e.g. cones cannot become flowers. This is a **historic constraint**.

Resources:

1. 21a Find the Other Tree Group Gymnosperms Student (Word and PDF)
2. 21a Find the Other Tree Group Gymnosperms Teacher (PPT and PDF)
3. 21b Angiosperms and Gymnosperms Student (PPT and PDF)
4. 21b Angiosperms and Gymnosperms Teacher (PPT and PDF)
5. 21c Unifying Life Student (Word and PDF)
6. 21c Unifying Life Teacher (PPT and PDF)

Procedures:

1. Ask the students to list all of the plants studied and what they have in common. They can use the Leafsnap app or their field guide. All studied plants have flowers, fruits, and broad flat leaves (they may not mention this characteristic). These plants are called ANGIOSPERMS (flowering plants):
    a. They are the most diverse group of land plants (between **250,000 to 400,000**).
    b. They are the plants we eat (e.g. wheat, rice, corn, etc.)
    c. The eucalyptus is the tallest angiosperm (over 100 meter, 32 stories tall).
    d. The smallest angiosperm is the duckweed (1 mm).
    e. They evolved 140 million years ago.
2. Ask the students to complete the Find the Other Tree Group worksheet **(Resource 1)** by browsing the Leafsnap database or field guide for trees that do not have flowers, fruits, or broad flat leaves (note: the Leafsnap app calls cones fruits; they are not). Students will find the common characteristics of gymnosperms, the plant group that lacks flowers and fruits. These characteristics are **cones & needles**. **Gymnosperm** means naked seed 9as opposed to a seed housed in a fruit as in angiosperms). They:
    a. Were the dominant plant group during the time of dinosaurs.
    b. Have naked seeds, unlike angiosperms, whose seeds are enclosed in the flower or the fruit derived from the flowers. Gymnopserm seeds do not develop inside a fruit and do not start out in flowers.

   c. Are wind pollinated with the pollen falling directly on the ovule.
   d. Include less than **1000 species** worldwide.
   e. Include the tallest tree in the world, a redwood tree, named Hyperion, discovered in California in 2006. It is 115.7 meters tall or 35 stories tall.
3. After students complete Resource 1, they complete Angiosperms & Gymnosperms **(Resource 3)** & Unifying Life **(Resource 5)** worksheets. The goal of Angiosperms and Gymnosperms **(Resource 3)** is for students to:
   a. Understand that **angiosperms** have **fruits** & **flowers** & **seeds**
   b. Understand that **gymnosperms** have **seeds**, but not fruits & flowers.
   c. Complete a matrix of characteristics that define the angiosperms & gymnosperms. They will use these characteristics to define the angiosperms and gymnosperms on the tree diagram on the next worksheet.

   The goal of Unifying Life (**Resource 5**) is for students to build a tree diagram that shows shared ancestry from the characteristics they derived in the Angiosperms and Gymnosperms (Resource 3) worksheet. Students will learn:
   a. That all **angiosperms** (most street trees) share a most recent **common ancestor** that had **flowers and fruits**.
   b. That all a**ngiosperms** & **gymnosperms** share a common ancestor with **seeds**.
   c. That all **vascular plants** (this group includes angiosperms, gymnosperms and ferns) share an **ancestor** with **leaves**.
   d. The **characteristics** that we see in tree groups **today** are present because they were **present** in the **ancestors** that lived a long time ago in the past.

Anticipated Outcomes:
Students will understand that:

- **Angiosperms** have fruits & flowers & seeds. They are **defined by** the presence of **flowers & fruits**.
- **Gymnosperms** have **seeds**, but do not have fruits and flowers.
- The group that contains **angiosperms and gymnosperms is defined** by the presence of **seeds**.
- All **angiosperms** (the street trees they studied this year and the corner store plants and fruits they know) share a common **ancestor** that had **fruits** & **flowers**.
- **All** the **trees** in the Leafsnap app and the trees in the field guide and trees generally (angiosperms & gymnosperms) share a common **ancestor** with **seeds**.
- **All vascular plants** (angiosperms, gymnosperms & ferns) share a common ancestor that had **leaves** and was **green**.
- Plants cannot suddenly evolve characteristics that may be useful for their success (e.g. trees with cones could not develop flowers & fruits to help with pollen and seed dispersal, even though that may increase their abundance in the future). This is **historic constraint**.
- The **characteristics** that we see in tree groups **today** like **flowers, fruits, & seeds** are present because they were **present** in their tree **ancestors** that lived a **long time ago**. These features **show** that they are **living** r**epresentatives** of the very distant **past**.

Lesson 22: Students Complete Their Tree Notebooks

Goals:
To wrap up student understanding about noticing, identifying, grouping, and common ancestry of street trees.

Resources:
1. Tree Notebook Student (PPT and PDF; found in Lesson 6)
2. Tree Notebook Teacher (PPT and PDF; found in Lesson 6)

Procedures:
1. Ask students to complete the final two pages of their tree notebooks (pages 25-26). Students will:
    a. Compare their tree to a classmate's tree.
    b. Find two relatives of their tree in the Leafsnap database or their field guide.
    c. Draw the leaf shape, leaf arrangement, fruits and flower characteristics of these trees.
    d. Draw these common characteristics on a diagram that shows the features of the common ancestor to these trees.
    e. Include one more plant of the diagram that is not as closely related.
    f. Draw the characteristics of its ancestor onto the diagram.
    g. Mark on the diagram that characteristic that was present in the common ancestor to all the trees on the diagram.
2. This activity summarizes the goals of this curriculum.

Anticipated Outcomes:
Students will understand that:
- The tree they observed all year is similar and different to other trees.
- The tree they observed all year is related to other street trees.
- Their tree and its relatives share a common ancestor that shares fruit, flower, and leaf shape and arrangement.
- Their tree along with other street trees shares a common ancestor with fruits and flowers. All street trees (that are angiosperms) have flowers and fruits.
- **All things that are alive today have features that they inherited from ancestors that lived a long time ago**.